BUTLER UNIVERSITY BOTANICAL STUDIES

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A POLLEN PROFILE FROM REED BOG, RANDOLPH COUNTY, INDIANA

By Charles D. Griffin

Sediments from lakes and bogs have given valuable records which indicate succession of forests and climatic changes since glacial retreat at the close of Pleistocene times in the geographical area now known as Indiana. The closing chapter of this history has, however, not yet been written, for every pollen profile adds new discoveries of variations in forest composition which may be due to difference in geographical location or to microclimatic variations. Thus, we might consider each new bog record a contribution toward reconstruction of forests of the past which covered the soils of Indiana. There are, especially, many unanswered questions with respect to forest succession along the line of junction between Early and Late Wisconsin glaciation in Indiana. Into this picture we fit the study of the pollen records from Reed bog where today corn fields mark the culmination of great vegetational changes which ranged from coniferous to primarily broad leaved forests.

Reed bog is located in the southern portion of Randolph County, Indiana, and is approximately 5½ miles north of the town of Modoc along Indiana State Highway 1. Central Randolph County marks the southern termination of the Union City Moraine which is the outer border of Late Wisconsin glaciation in eastern Indiana. Reed bog, therefore, is associated with the Bloomington Morainic System of the Early Wisconsin drift sheet.

A half mile north of Reed bog is the Cabin Creek raised bog studied by Friesner and Potzger (5). A comparison will be made between the pollen profile of Reed bog and those of Cabin Creek and other Early Wisconsin bogs in Indiana.

METHODS

Because Reed bog has been under cultivation, it was considered wise to omit peat samples near the surface because of the soil disturbance and effect of oxidation upon pollen. The first sample, therefore, was obtained at the 3-foot level.

The depth of the bog is 34 feet. Samples of peat were taken at

each foot-level from three feet below the surface to 34 feet below with a Hiller type borer. Additional samples were taken at 12'3", 13'6" and at 22'5" because of a visible change in the color and texture of the peat at these points. The preparation of the peat for counting of fossil pollen was done according to the Geisler alcohol method. The stain used was a 1% aqueous Gentian Violet and the mounting medium was glycerin jelly. Approximately 200 pollen grains of significant tree genera and species were counted at each level except near the surface where the pollen was sparse.

An attempt was made to distinguish between *Picea glauca* and *P. mariana* and between *Pinus strobus* and *P. banksiana*. The entire length of the grain (including the bladders) was used for differentiation. The depth of the bladders (measured between proximal and distal root junctions of bladder with body) and length (long axis) of the body were also used to differentiate damaged or half grains. Based on modern pollen from prepared slides at the Butler University Botanical Laboratories, the above-mentioned species were differentiated according to the following measurements in microns. The figures in parentheses denote means.

	Entire length	Body length	Wing depth
Picea mariana	70-90 (81)	52-75 (60)	34-59 (48)
" glauca	88-108 (101)	68-87 (81)	51-69 (61)
Pinus banksiana	57-67 (63)	38-59 (42)	25-33 (29)
" strobus	51-85 (71)	39-55 (51)	29-47 (39)

OBSERVATIONS

The percentages of fossil pollen for each level are presented in graphic form in figure 1. Abies is represented at the 34-foot level or at the bottom of the deposit by a percentage of 5.5. This percentage gradually increases with several slight fluctuations to a maximum of 14.5% at the 19-foot level, after which the percentage suddenly drops to 1.4. It appears in low percentages for several levels and is absent above 12'3".

Picea glauca and *P. mariana* show two general maxima with the peak for *P. mariana* in each case occurring in higher levels than the peak of *P. glauca*. Peaks for *P. glauca* occur at the 33- and 20-foot levels. For *P. mariana,* the peaks come at the 32- and 16-foot levels. The minima for both species are, in general, between the 23- and 26-foot levels. Above the 13-foot level, Picea has a small percentage. However, it occurs in every foot-level sampled. From the limited

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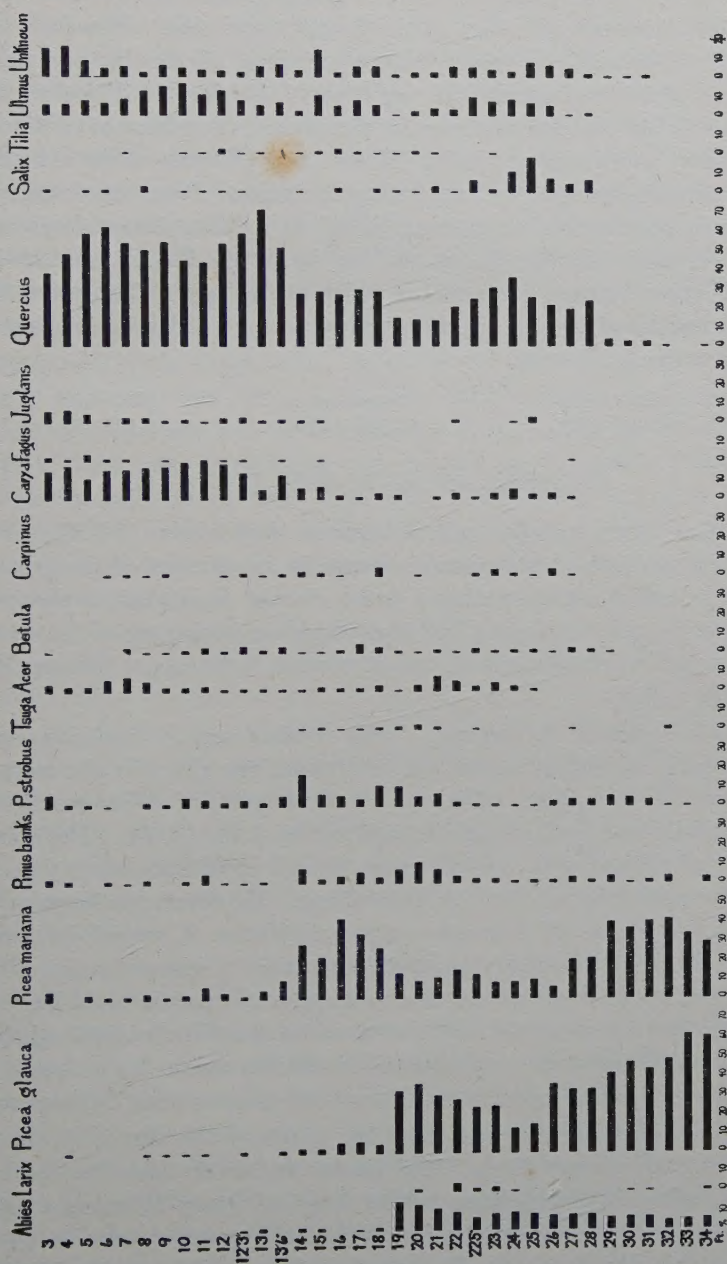
amount of pollen deposited, one might conclude that the two Pinus species were not abundant in the forest association. However, both tend to show higher representation at time of the Picea maxima. Pinus also is represented in every level. During the Picea minima, there is an obvious increase in abundance of pollen of deciduous genera. Acer, Carya, Salix, Ulmus, and Quercus show a marked percentage increase, decline during the second Picea maximum and rise to prominent abundance at 13′6″ to indicate forest dominance.

At several foot-levels, particularly in the 19-, 20-, 21- and 26-foot levels there appear Picea grains which are of larger dimensions than those of *Picea glauca*. The general size range and mean of these in microns is as follows:

Entire length	Body length	Wing depth
96-137 (121)	64-101 (83)	48-103 (78)

SIGNIFICANCE OF THE FINDINGS

The three samples taken between foot-levels (12′3″, 13′6″, 22′5″) because of conspicuous change in appearance of the peat did not reveal a correspondingly great change in forest composition. However, the sample at 13′6″ does mark the beginning of the second decrease in *Picea mariana* and a general increase in Quercus and Carya pollen.

Picea glauca, P. mariana, Pinus strobus and *P. banksiana* were separated according to the size determinations given in the methods section of this paper. The mean body lengths of these grains correspond, in general, with those reported by Cain (2, 3). The abundance of Pinus pollen was not great enough to indicate more than the presence of two species in the Reed bog. However, the large pollen grains of Picea which became very conspicuous at several foot-levels (19, 20, 21, 26) indicate a probable invasion by a new species. This may be a species which has since become extinct or it could be *Picea rubra,* for it is noted with interest that the mean body length of these grains (83 microns) corresponds with the mean body length of modern *P. rubra* pollen reported by Cain (2) as being 82.8 microns.

The pollen spectrum of Reed bog is unusual in that it shows two peaks in abundance of the Picea species and a corresponding increase of Quercus between them. Other bogs of Early Wisconsin origin located farther south of the Late Wisconsin terminal moraine do not show this phenomenon. In these bogs, the pollen profile of Picea

shows a sudden or progressive decline from maximum abundance without a succeeding period of recovery. It would seem evident, therefore, that the advance of the Late Wisconsin ice sheet had a pronounced effect upon the vegetation growing immediately below its termination (Union City Moraine) and within the upper limits of Early Wisconsin glaciation in eastern Indiana. In explanation, if a long interglacial warm period caused ice to melt northward beyond the boundary of Indiana, one would expect to find striking successional changes from spruce to broad leaved forests and a reversal in such forest succession with advance of the Late Wisconsin ice sheet.

While the profile from the Reed bog is not an exact counterpart of that from Cabin Creek raised bog, there are some similarities. We find in both bogs the Picea peaks alternating with the two Quercus peaks and the general succession from dominance of spruce to a crown cover of deciduous trees (Quercus, Carya, Acer, Juglans, Ulmus). The pollen spectrum of *Picea mariana* in Cabin Creek bog shows the same behavior in that, with a decrease of *P. glauca* there is a corresponding increase in *P. mariana*. Also, Picea is represented in all levels in both bogs. But, in Cabin Creek, the dominance of Picea occurs almost to the top. This can possibly be explained as being due to the slower deposition in a raised bog. Cabin Creek raised bog must have increased in depth of peat much more slowly, especially towards upper foot-levels, than the Reed bog. The former was influenced by air environment with accompanying oxidizing influences, hence less peat was accumulated in similar time intervals. We must, therefore, read into its foot-levels a much more compacted time scale than into the water-deposited plant remains at Reed bog. The two bog histories are also similar in that Pinus tends to increase with the increase of *Picea mariana*.

It is not so easy to find point-for-point similarities between the two bogs in Randolph County and other bogs of Early Wisconsin origin in Indiana. However, it must be taken into consideration that all other bogs [Otterbein, Richards (10), Yountsville, Swickard (11), Fox Prairie, Prettyman (9)] except the one at Kokomo studied by Howell (6), were much farther removed from the junction boundary of Early and Late Wisconsin glaciations. In these other bogs, Picea, after a high maximum, is usually on the decrease when Quercus appears, and there is no indication of alternating maxima between the two species as there is in the Randolph County bogs. Picea generally

does not persist even in low percentages to the upper-profile levels of other Early Wisconsin bogs as it does in Reed and Cabin Creek bogs. This persistence of Picea is usually characteristic of bogs of Late Wisconsin origin, Swickard (11). One similarity appears to be that Pinus usually persists to the top level in all the bogs of Early Wisconsin glaciation but never shows a definite climax. However, Bacon's Swamp, studied by Otto (7), does show a period of Quercus decrease with a corresponding increase in Pinus. Cranberry Pond, analyzed by Barnett (1), shows a slight Pinus maximum, but it is before the appearance of Quercus.

In conclusion it might be pointed out specifically that the record of late entrance of Carya into the broadleaved forest complex, the erratic and sparse representation of Tsuga and the general trend in succession towards a mixed mesophytic climax, mark the Reed bog profile as typical of Indiana bogs in general.

SUMMARY

1. The study presents a pollen analysis of a bog in an eastern Indiana locality which is associated with the Bloomington Morainic system of the Early Wisconsin drift sheet.

2. Distinction is made between *Picea glauca* and *P. mariana,* and between *Pinus strobus* and *P. banksiana* pollen on basis of size.

3. Abies occurs in low percentages in the lower levels of the bog.

4. The pollen spectrum of Reed bog shows two peaks of prominent abundance of the Picea species and a corresponding increase of Quercus and other deciduous genera between the two Picea maxima. After the second Picea decline, Quercus, along with several other deciduous genera, later including Carya, predominate to the upper levels of the bog.

5. Pinus occurs in low percentages in every level of the bog, but it tends to show higher representation at the Picea maxima.

6. Large pollen grains of Picea are very conspicuous at several foot-levels, suggesting possible presence of a third species of this genus.

ACKNOWLEDGMENTS

Botany Department of Butler University for collection of the peat samples. Appreciation is also expressed to Dr. A. G. Vestal of the Botany Department of the University of Illinois for helpful suggestions during the writing of this paper.

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TABLE I
Pollen percentages—Reed bog

Foot level	Abies	Larix	Picea glauca	Picea mariana	Pinus banksiana	Pinus strobus	Tsuga	Acer	Betula	Carpinus	Carya	Fagus	Juglans	Quercus	Salix	Tilia	Ulmus	Unknown
3				4.8	2.9	6.7		3.8	1.0		14.4	1.9	5.8	37.4	1.0		5.8	14.4
4			0.8		1.6	1.6		2.4			17.7	0.8	6.5	47.6	0.7		5.6	15.3
5				2.7		1.4		2.7			10.9	3.4	4.1	58.2	0.9		7.5	8.2
6				1.8	1.4	0.5		6.0		0.9	15.1	0.9	0.5	61.9			6.0	4.1
7				1.5	0.5			7.7	2.6	1.0	15.4	1.0	2.6	53.8			8.2	5.1
8				3.0	2.0	2.0		5.0	0.5	0.5	16.6		2.5	49.7	3.0	0.5	12.6	2.0
9			0.5	1.6		1.6		2.0	0.5	1.6	16.8	0.5	1.0	53.4			14.7	5.8
10			0.5	2.1	1.6	4.7		2.1	1.6		19.3		1.6	44.3	0.5	0.5	16.7	4.7
11			0.5	6.4	4.8	3.7		2.7	2.7	0.5	19.7	0.5	0.5	43.1	0.5	0.5	10.6	3.7
12	0.5			3.7	0.5	2.1		1.0	1.0	1.6	18.3	0.5	2.1	52.9	0.5	2.1	12.6	2.6
12.25	1.5		1.1	1.6	0.5	3.3		1.6	3.3	0.5	13.6	0.5	2.7	58.7	0.5	0.5	7.6	2.2
13				4.5	1.0	2.0		1.5	1.5	1.0	5.0		1.0	70.5		0.5	5.0	5.5
13.5	1.5		1.5	9.8		5.2	0.5	1.0	3.1		12.4		1.5	51.0			6.7	6.2
14	1.1		2.6	28.2	7.2	16.4	1.1	1.0	0.5	2.1	5.6	0.5	1.0	27.2	0.5	0.5	2.1	3.1
15			2.1	21.7	2.1	6.3	0.5	2.1	0.5	1.6	6.3		1.1	28.0		1.1	10.6	13.6
16			5.4	41.4	3.9	5.4	0.5	1.5	1.5	0.5	2.0	0.5		26.6	2.0	2.5	4.9	2.0
17	0.5		5.6	33.7	5.6	3.6		1.5	4.6		1.0			29.6		1.0	7.7	5.1
18	1.4		4.3	26.2	2.9	10.5	1.0	2.9	2.9	4.3	2.9			28.1	1.9	0.5	5.2	5.2

TABLE I—(Continued)

Pollen percentages—Reed bog

Foot level	Abies	Larix	Picea glauca	Picea mariana	Pinus banksiana	Pinus strobus	Tsuga	Acer	Betula	Carpinus	Carya	Fagus	Juglans	Quercus	Salix	Tilia	Ulmus	Unknown
19	14.5		32.0	13.0	7.0	10.1	1.5	0.5	1.0		2.0			14.6	1.0	0.5	0.5	1.0
20	13.0	1.0	35.8	9.0	10.9	5.2	2.6	3.1	0.5	0.5				13.5	0.5	1.6	2.1	2.1
21	11.2	4.0	29.6	10.7	7.2	6.7	1.5	7.7	1.5		1.0			13.3	3.1	0.5	3.6	2.1
22	9.1	1.6	27.3	14.6	3.5	2.0		5.6	0.5		3.0		1.5	20.2	0.5		3.0	5.1
22.5	6.4	2.1	23.5	12.3	2.1	1.1	0.5	2.7	2.1		1.0			24.6	6.4		9.6	4.8
23	8.3	0.5	24.0	8.3	2.1	1.0		4.2	1.0	1.1	3.1			30.2	1.6	0.5	6.8	3.6
24	8.7		12.8	8.7	1.0	0.5		2.6	1.5	3.1	5.1		0.5	35.7	10.7		8.2	2.6
25	8.2		14.8	9.3	1.6	0.5		1.1	1.6	1.0	2.7		2.7	25.1	18.0		6.6	7.1
26	6.8		35.4	6.2	1.6	2.6			0.5	0.5	3.1			21.1	7.3		5.3	5.8
27	7.4		32.4	20.2	3.2	3.7	0.5		2.1	3.7	1.1	0.5		19.1	4.3		0.5	4.3
28	7.8		32.8	20.8	1.6	3.1			1.6	0.5				23.4	6.3		1.0	1.6
29	6.0		40.9	39.9	3.5	5.1			0.5					3.5				0.5
30	8.5	0.5	46.5	36.5	0.5	4.5								2.5				0.5
31	8.5	0.5	43.0	40.0	1.5	3.0								2.5				0.5
32	4.5		48.0	41.5	3.5	0.5	1.5							0.5				1.0
33	5.0		61.0	33.5		0.5												
34	5.5	1.0	60.0	29.0	3.0									0.5				1.0

HISTORY OF FORESTS IN THE GLACIAL LAKE CHICAGO AREA[1]

By G. K. Guennel

By means of pollen studies it has been possible at least to venture estimates of the ecological conditions which existed and developed during post-glacial periods. Climate is no doubt the most important factor in determining the extensive formations of vegetations and their replacements. Weaver and Clements (20) state: "Climate may produce new areas for succession through the destruction of existing vegetation." If this be true, then the pollen analyst can estimate, on the basis of forest types as indicated by fossil pollen findings, what climatic conditions prevailed over wide geographic areas, since the forest types would be directly dependent on the climate, making the two synonymous within greater or lesser degree. While to date 22 Indiana bogs have been studied in detail, the overall picture of climatic and vegetational changes within the state is still somewhat incomplete. As new discoveries are being added to the present store, the picture of past vegetation evolves more clearly, and this in turn gives an estimate of the climatic conditions which prevailed since the retreat of the continental ice sheets which once covered much of Indiana.

Indiana is of special interest, as well as importance, in this respect, since it has glaciated as well as unglaciated topography and so involves important border areas. According to Malott (10) there is a driftless or unglaciated triangle in south-central Indiana. Three major glacial periods are recognized in Indiana, viz., the Illinoian, the Early and the Late Wisconsin. Since neither of the successively later ice sheets extended as far southward as its predecessor, we have exposed in the state a wide belt of each of these periods. Unfortunately no bogs have been found to date on the Illinoian till plain. The border line between the Illinoian and Early Wisconsin glaciations runs from Vigo county in the west to Franklin county in the east. The border of the Late Wisconsin sub-stage extends from Benton county on the western border to Randolph county in the east.

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[1] A portion of a thesis submitted in partial fulfillment of the requirements for the Master of Science degree in the Division of Graduate Instruction, Butler University.

Friesner (3), in correlating the glaciations with the effects they had on plant life, states: "These alternate southward and northward movements of ice and plants probably occurred many times in eastern North America. Indiana was a critical area for this plant-climate struggle because the edges of maximum extension of each of the last two ice sheets (Illinoian and Wisconsin) are to be found within her borders."

The pollen profiles of Pinhook and Merrillville bogs presented in this paper, represent a further contribution to the history of plant successions since the recession of the ice sheets. Both bogs are found within the boundary of the Late Wisconsin ice sheet. Pinhook bog is located west of La Porte in La Porte county, while Merrillville bog is in Lake county, north of Crown Point.

Glacial Lake Chicago, the ancestor of Lake Michigan, extended slightly farther south than the present shore line and was apparently bound in by the Valparaiso moraine which extends across Lake, Porter, and La Porte counties.

METHODS

The peat samples from Pinhook bog were collected in the fall of 1940 and those from the Merrillville bog in March 1948. Several trial borings were made in each bog in order to be certain that the deepest part of the basin was being sampled and thus assure getting a complete profile (Potzger, 12). Samples were taken at every foot-level, including the surface layer except at several foot-levels in the Pinhook bog where no samples were obtainable due to the fluid or gelatinous nature of the sediments. In the Merrillville bog samples were taken at closer intervals at a few critical levels.

The peat samples were prepared for study according to both the alkali and the alcohol method (Geisler, 4). The former proved better for certain badly dried-out samples. Slight modifications were made in following the two techniques. In order to minimize damage to the rather delicate fossil grains, only the first step of the KOH method was employed, that is, no centrifuging or decanting was undertaken. Also, instead of applying glycerin after boiling in KOH, pre-stained glycerin jelly was used. This process of using pre-stained jelly is also a slight deviation from the Geisler method. Instead of staining the material for each given foot-level with gentian violet, the glycerin jelly was stained, thus eliminating one step in preparing the material for study.

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Publications by Sears (17), Erdtmann (2), Wodehouse (21), and Wilson and Webster (20), together with slides prepared from known pollens of present-day species, were used to verify classification of fossil grains. The final word, however, on any questionable grain was given by Dr. Potzger. Two hundred tree pollens were counted at each foot-level, except at the surface and at the 27-foot level of the Pinhook boring. Because of the extreme scarcity of pollen, only 100 and 160 respectively were counted at those levels. Forty slides had to be prepared before the 160 pollen grains of tree species were obtained at the 27-foot level. A similar difficulty was encountered in the Merrillville boring. The lowermost three levels (34.5, 34, and 33.25 feet) yielded so little pollen that the first- and last-mentioned levels were omitted from the profile. At the 34-foot level 50 grains were counted. The sediments representing these three samplings were sandy marl, but the next sample, at the 33-foot level, was pure marl and yielded sufficient pollen for complete counts. Less than 200 pollen grains were counted at the following foot-levels: 34 (50); 10 (100); 8 (100); 6 (115); 5 (75); 4 (100); 3 (100); 2 (100); 1 (100) and 0.25 (50). The 2.5- and 1.5-foot levels were also omitted in the graphs because of the small number of tree pollens present in the sediments. Erdtmann (2) and Sears (17), as well as Potzger (12), advocate counting 200 grains. Barkley (1) says: "There is little significant shifting of relative percentage beyond the 200 count."

Shrub and herb pollens, as well as spores of pteridophytes and mosses were tabulated but not included in the graphs and tables. Tetrads and clusters of grains which came from the same anther, as evidenced by anther remains, were counted as one grain only. Two magnifications were used in the examination of the slides, 150x for locating the grains, and 645x for measuring and identification. A binocular monobjective type of microscope with mechanical stage was used.

SPECIATION

No difficulty was encountered in distinguishing the three main genera possessing wing-type pollen, namely Abies, Picea, and Pinus. The outstanding features enabling differentiation were size and "re-entrant" angle of the wings. The latter feature sets off the spruces from the other two. Pollen grains of Picea have no distinct

angle at the point where the bladders meet the tube cell, while in Abies and Pinus pollen a sharp angle is formed at that point (fig. 2). In size-range there is an overlapping between Abies and *Picea glauca,* the largest spruce grain. Abies grains ranged from 90 to 115.2 microns, with the average at 104.7, and *Picea glauca,* with an average of 98.28, ranged from 92.4 to 104.4. When wings are present (some

Fig. 1

Legend

Glacial lake Chicago	Late Wisconsin		
⊙A Pinhook Bog	Early Wisconsin		
⊙B Merrillville Bog	Illinoian		

Fig. 2.

Pinus resinosa

Picea glauca

Abies balsamea
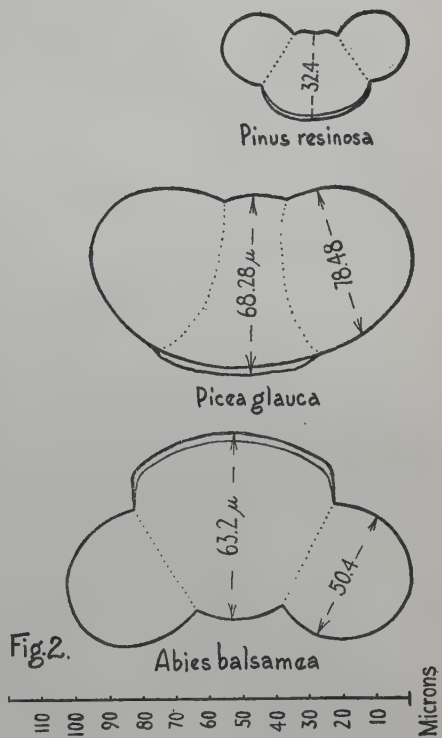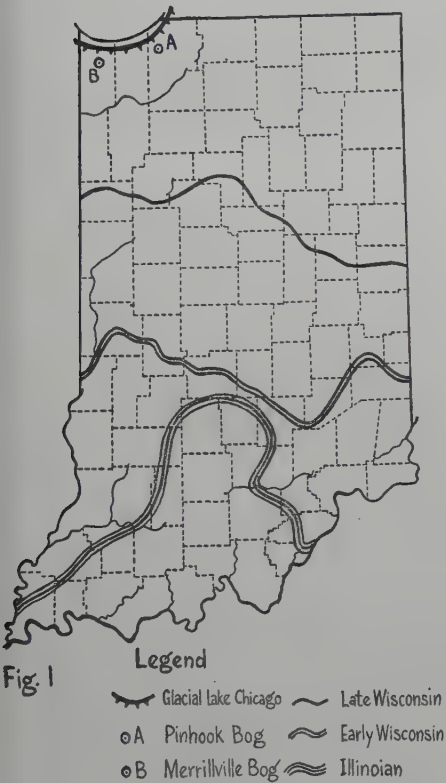
Microns

fossil grains are broken or crushed) the two types of pollen can be differentiated readily. Abies wings measured from 36 to 57.6 microns, whereas *Picea glauca* wings showed a range of 60 to 78. The modes for size of the wings are 75 microns for *P. glauca* and 45 for Abies, with average of 78.48 and 50.4 respectively. The measurements of the wings were taken parallel to the lines of attachment, at

the greatest diameter (fig. 2). A similar situation was encountered in differentiating the smaller spruce, *Picea mariana,* from the larger pines, since the sizes overlap. Again, the re-entrant angle usually sufficed as means of distinguishing, since pine pollen is similar in shape to that of Abies.

The real difficulty was met when attempting to differentiate Pinus pollen on the basis of size. That there are differences in size was apparent, but the grains of the various species seem to overlap to such an extent that it was practically impossible to determine the species definitely, at least in the overlapping size ranges. After a brief study of modern pollen from eight species of pines, the author risked classifying the fossil grains into *Pinus strobus* and *Pinus banksiana*: grains above 60 microns in overall size were termed *P. strobus,* and the grains measuring under 60 were classified as *P. banksiana.*

RESULTS

Pinhook Bog

Results from study of the Pinhook bog are shown in table 1 and fig. 3. A graphic presentation of the main forest types, as indicated by pollen frequency, is given in fig. 4. The percentage figures include only tree pollens, since the study concerned itself primarily with forest succession.

The Pinhook profile shows a strong Abies-Picea association in the lower foot-levels. At the 54-foot level *Picea glauca* and *P. mariana* combined constitute 81% of all the tree pollen. Abies appears to have been definitely associated with Picea, as evidenced by the simultaneous decline of the two genera. After dominating the profile for about one-third of its depth, Picea, with the exception of several brief gains, never again attains a dominating position. Abies is completely lacking above the 34-foot level.

Although Pinus is present from the beginning it shows no dominance until after the fir-spruce decline. Following a peak at the 39- and 38-foot levels, *Pinus banksiana* gives way to *Pinus strobus.* The latter reaches its peak at the 36-foot level. At the 34-foot level both pines decline rather abruptly, never to exceed 12% of the tree pollen total at any succeeding level.

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Fig. 4.   PINHOOK BOG

                      Fir-Spruce
                      Pine
                      Oak-Hickory

Fig. 6.   MERRILLVILLE BOG

                      Fir-Spruce
                      Pine
                      Oak-Hickory

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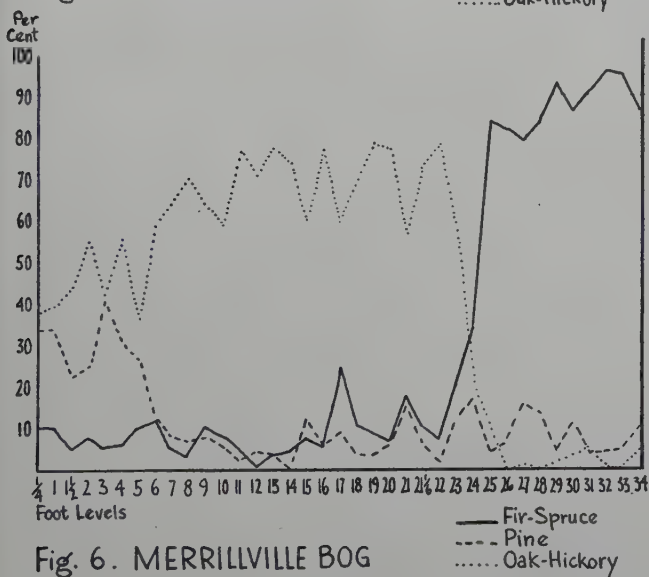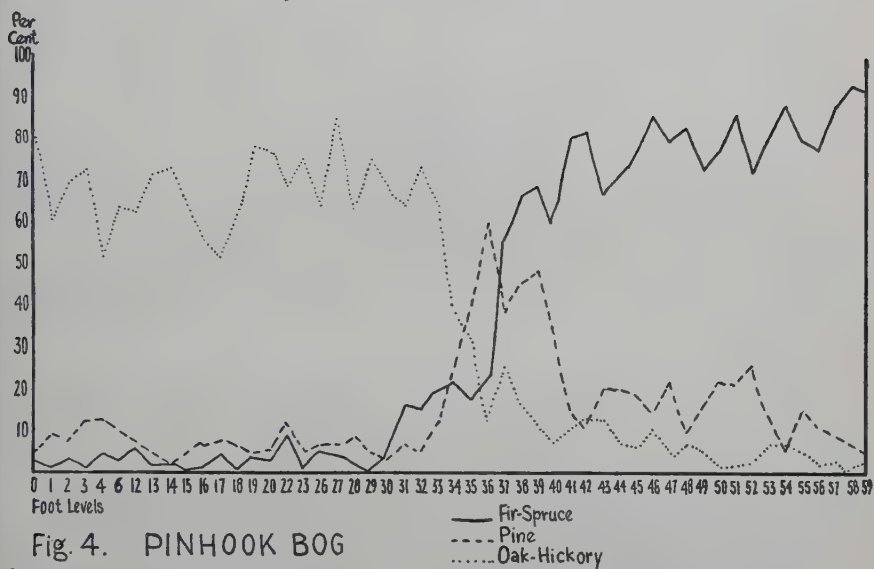
With the decline of Pinus, Quercus increases in dominance. While oak pollen in small quantities was present even in the samples from the lowest levels, it contributed most pollen from the 35-foot level upward, reaching a maximum of 78% at the 27-foot level. Carya made several appearances throughout the Picea-Pinus period, but it first becomes conspicuous as an associate of Quercus from the 33-foot level upward. Of the other genera represented, only Betula and Salix show more than 10% representation. The latter attained a peak of 17.5% at the 31-foot level and Betula showed 12% at the 38-foot level.

Merrillville Bog

Results from study of the Merrillville bog are shown in table II and fig. 5. The succession of the main forest types or associations is shown in fig. 6. The lowermost layers of the Merrillville bog contained only pollen of Abies, Picea and Pinus. The first-mentioned genus attains a maximum representation of 23.5% at the 26-foot level and nearly disappears after the 23-foot level. *Picea glauca* starts with 62.5% at the 34-foot level, drops to 28.5% at the 27-foot level, and after attaining 45.5% at the 25-foot level declines abruptly at the 23-foot level. At the 27-foot level *P. mariana* attains its peak (43%), making up for the drop in *P. glauca* at that level. Both spruces participate in the spectrum to the surface, but do not make any serious advances toward dominance.

Pinus strobus was present at every foot-level. In the lower half of the bog it reaches its maximum at the 24-foot level with a frequency of 16%, while near the surface it rises to real prominence, at two foot-levels even exceeding Quercus. Its maximum representation (39%) is attained at the 3-foot level. *Pinus banksiana* never gains great abundance even though it was present throughout the profile.

In the lower third of the profile, Quercus appears in very small percentages but at the 24-foot level it first shows signs of importance with 19% representation. At the next higher foot-level it increased to 49%, while at the 20- and 19-foot levels it attains its peak of 70.5 and 71.5% respectively. It remains prominent throughout the upper layers and from the 5-foot level on it meets competition from *Pinus strobus,* which actually outnumbers it at the 3- and 1-foot levels.

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MERRILLVILLE BOG   PINHOOK BOG

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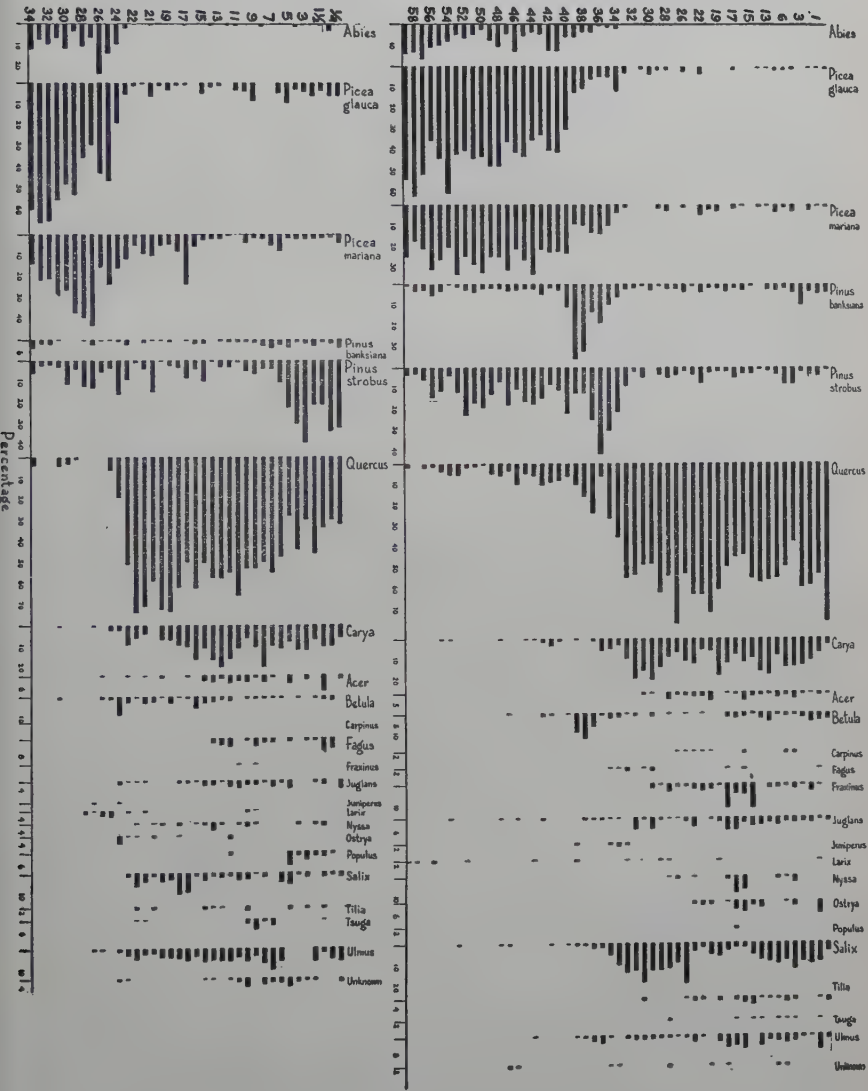
Here, as in the Pinhook bog, Carya does not reach a high percentage of representation but becomes an important associate of oak. None of the other genera recorded in the spectrum display great importance from the standpoint of numerical representation.

DISCUSSION

Despite its limitations, pollen analysis is a valuable aid to reconstruction of vegetations as they occurred in post-glacial time. The spectra of the two bogs studied show that the forest type of northern Indiana, immediately following glaciation, resembled closely the boreal or northern forest of today. When one considers that the lower deposits represent 400 to 500 years in time per foot-level (Potzger and Wilson, 16), it is understandable that considerable change in forest composition due to local fluctuations and conditions could have taken place, which in turn fostered, or at least permitted changes in generic representation in the associations. The danger of correlating slight increases or decreases in frequency of a certain pollen type with a major climatic change is ever-present when interpreting fossil pollen findings. We should, perhaps, make interpretation lean more heavily on ecological surveys of present-day vegetation. Potzger (13) in such a correlation study in central northern Wisconsin and upper Michigan, discusses microclimatic and edaphic factors as influences in determining forest covers. Potzger and Friesner (15), in studying present-day vegetations in central Indiana, found a mixed mesophytic forest (Acer-Fagus dominance) on north-facing slopes, while the south-facing slopes were vegetated by a typical oak-hickory forest type. The ridges terminating the slopes represent only slight distances, and the slopes in question are within the same climatic range or belt. Such forest distribution phenomena show that macroclimate is not the only factor which determines and controls plant associations. Potzger (14) breaks down microclimate into various constituent influences, such as evaporation, temperature, moisture, and edaphic relations.

The northern forest, as indicated by Picea and Abies, declined suddenly in both profiles. This is a characteristic but baffling phenomenon in the Lake States region, as pointed out by Potzger (13). This abrupt decline of fir-spruce is coupled with an equally sudden rise of pine in the Pinhook profile. In the Merrillville record the transition is more direct to a deciduous forest type, namely to an oak-hickory

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association. The sudden decline of the boreal forest agrees with previous findings in Late Wisconsin bogs of northern Indiana. Keller (7) reported abrupt changes from Abies-Picea to Pinus for Jeff, Culver, and Shipshewana bogs in Wells, Starke, and La Grange counties, Indiana, and Smith (18), as well as Howell (6) found the same behavior of these boreal genera in the profiles of Lake Cicott and Kokomo bogs. Moss (11) reported a similar sudden transition in Silver Lake bog (Kosciusko county) and Altona bog (De Kalb county), while in Round Lake bog (Starke county) Hamp (5) found a direct transition from Abies-Picea to oak as in the Merrillville profile.

In the light of the uniformity of persistence and decline of spruce-fir forests in a number of northern Indiana bog profiles, it can be assumed that the climate immediately following glacial recession was cold and moist. That climate is directly responsible for forest climax changes, although not the sole factor, is further proven when sudden changes occur between two widely diverse forest types (coniferous and deciduous). The Pinhook records show just such a sudden transition. After pine dominated during a period in which five foot-levels of peat accumulated, Quercus increased greatly resulting in an equally sudden drop of pine (figs. 3 and 4). Moss (11) says: "In all Indiana bogs the transition from a coniferous to a deciduous forest is sudden, i.e., within the range of one foot-level." This occurred in the Pinhook spectrum at the 34- and 33-foot levels. The Merrillville profile shows an even more pronounced transition from a boreal type of forest to an oak-hickory association. At the 25-foot level the conifers Abies, Picea, and Pinus combined totaled 87.5%, and oak and hickory only 8.5%. At the 23-foot level a reversal is evident in that oak and hickory here contributed almost twice as much pollen as the conifers. Lindsey (9), in his preliminary study of Merrillville bog, showed the same abrupt transition from coniferous to deciduous forest. This change indicates that the climate became warmer and drier favoring a Quercus-Carya climax. The Merrillville bog record, in its lack of a pronounced pine dominance, differs from that of the Pinhook and all other Late Wisconsin bogs investigated in Indiana, except the one at Round Lake studied by Hamp (5).

The present study shows that care must be exercised in the interpretation of climatic factors from pollen profile data of single areas. The two bogs are located within the same latitude and they are sepa-

rated by only 25 miles in an east-west direction, yet there are forest differences which might indicate major climatic differences between the two places. This reminds one forcefully that variation (microclimatic) in environmental control of forest types must find a place in interpretation of pollen profiles. The Merrillville area did not experience the pronounced pine period which is so evident in the Pinhook profile, and constitutes a characteristic feature of Indiana bogs located in Late Wisconsin territory. If we disregard microclimatic control in our interpretation of the climate-vegetation complex at the two locations in question, we would conclude that the transition pine period, so evident at Pinhook, represents a slower climatic change, i.e., the cold and moist climate favoring Abies and Picea, first changed to a cool stage, permitting pine to express itself in proportions of dominance, whereas at Merrillville the pine transition was wanting, indicating a sudden change from cold-moist to a drier, warmer climate. Such an assumption is, of course, absurd. If macroclimate is too encompassing to account for such local differences, then microclimatic factors must be assumed in control. We use such procedure in ecological surveys of forests of today.

Oak is definitely the most important genus in both profiles, both in its own right and in combination with other genera in various associations. In the Pinhook profile one could almost speak of a transitional oak-pine period, as indicated by the pollen representation in the 37- to the 34-foot level inclusive. A similar oak-pine complex was noted in the Merrillville bog at the 24- and 23-foot levels.

The Quercus dominance in Pinhook shows Carya as a strong associate. The high percentage of Salix pollen no doubt indicates shallowing water in depressions rather than changes in either climate or the climax forest. Carya and Salix, as well as the total associated genera, could hardly be considered serious competitors of oak. A percentage decrease of Quercus and Carya, while the 18- to 13-foot levels were being deposited, is due to invasion by such genera as Ulmus, Fraxinus, Juglans, Nyssa, and Tilia, none of which ever really competed with oak on sandy uplands. This increase may be interpreted (although minor oscillations and fluctuations should not be taken too critically) as indicating a moderating climate, for as Smith (18) says: "While Ulmus, Juglans and Populus indicate moderating climate, they only represent a transitional complex of the deciduous forest, a gradual filling in of wet lowlands." Disregard-

ing minor intrusions by mesophytic genera and the prominent increase of *Pinus strobus* due to relic colony development, an oak-hickory association represents the climax forest at both locations.

The general successional trend of Merrillville bog follows closely that of Pinhook, except for a striking rise of white pine in the upper foot-levels. This rise, however, serves to illustrate further that fossil pollen findings, i.e., fluctuations of frequencies, do not necessarily always indicate major climatic changes. White pine dominance recorded at two-foot levels and close competition with oak in the other upper levels, would certainly seem to indicate a definite change in climate. Since, however, it is known that Merrillville bog was covered with a stand of *Pinus strobus* up to a few years ago, the climatic factor has to be disregarded.

After having made quadrat studies of the vegetational cover of Merrillville bog, Lindsey (8) found that *Pinus strobus* showed a 100% frequency in all 25 of the 10-meter quadrats surveyed. He states: "*Pinus strobus* is the important tree at present, but is doomed to yield its position to the incoming oaks. A pine seedling is rarely found on the forest floor, while oak seedlings are common, thus indicating that the pines are yieldng to an oak succession."

Pinus strobus persisted as an unusual relic colony until about 1940 when a fire eliminated all but one small tree. The pollen profile (fig. 3 and table 1) shows a dual dominance of oak and pine in the most recently deposited peat layers. The deposits of oak pollen grains apparently were contributed by the trees surrounding the bog proper, while the white pine pollen was deposited by the stand on the bog mat. If we merely consider fossil pollen frequency it is easily seen how climatic misinterpretations could result. It certainly could not be discounted that the abundance of pine pollen indicates a more or less proportional index of actual tree abundance, but equally certainly it would be erroneous to consider the Merrillville region as having borne a climax of pine and oak. On the basis of Lindsey's findings, it can be stated that *Pinus strobus* was not a participant in the overall climax forest of northern Indiana, or even in the region immediatley adjacent to and surrounding Merrillville bog, but that it was restricted to the bog mat itself.

These very unusual records are especially a fine recommendation for the reliability of pollen profiles in revealing the character of the forest of the area. They are at the same time highly dramatic

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records. They show that centuries ago white pine multiplied and expanded into the gradually solidifying bog mat. We saw the culmination of this conquest favored by microclimate, viz., a magnificent stand of pines. The closing chapter was cruel, swift and final. A grass fire extended its destruction into the bog, and in the span of minutes the activity which had continued for centuries stopped short. There remains today on the Merrillville bog mat one lone tree.

SUMMARY

1. Pollen studies of Pinhook and Merrillville bogs, located in La Porte and Lake counties, respectively, in northern Indiana are presented in this paper.

2. Forest succession, as indicated by the Pinhook profile, was: Picea-Abies to Pinus to Pinus-Quercus to Quercus-Carya.

3. At Merrillville the succession was: Picea-Abies to Pinus-Quercus to Quercus-Carya to Pinus-Quercus-Carya. The mid-profile Pinus period was wanting.

4. An increase of white pine pollen in the upper levels of the Merrillville profile was due to local (microclimatic) rather than climatic factors.

5. The following climatic changes can be assumed on basis of the two spectra: cold-moist to a cool-drier terminated by a warm-dry climate.

6. Special data bearing upon the reliability of pollen profiles are presented. The pollen record in the topmost layers of Merrillville bog is certified by a recent ecological survey.

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TABLE I
Percentages of tree pollens—Pinhook bog

Foot-level	Abies	Acer	Betula	Carpinus	Carya	Fagus	Fraxinus	Juglans	Juniperus	Larix	Nyssa	Ostrya	Picea glauca	Picea mariana	Pinus banksiana	Pinus strobus	Populus	Quercus	Salix	Tilia	Tsuga	Ulmus	Unknown
0	0.	1.	3.	0.	3.	0.	0.	2.	0.	0.	0.	0.	1.	1.	4.	1.	0.	76.	4.	2.	0.	2.	0.
1	0.	1.5	3.5	0.	7.	0.5	0.5	1.	0.	0.5	0.	6.	0.5	0.5	4.5	4.	0.	53.	9.	0.5	0.5	7.	0.
2	0.	0.5	4.	0.	10.5	0.	3.5	2.5	0.	0.	0.	0.	0.5	2.5	3.5	3.5	0.	58.5	10.	0.	0.	0.5	0.
3	0.	1.	2.	0.	13.	0.	0.5	0.	0.	0.	0.	0.	0.	0.	10.	2.	0.	59.5	12.5	1.5	0.	1.	0.
4	0.	3.	1.	1.5	13.5	0.	2.	2.5	0.	0.	3.	2.5	1.	3.	4.	8.	0.	37.5	12.5	2.	0.5	3.	0.
6	0.	1.5	1.5	1.5	14.	0.	1.	2.	0.	0.	0.5	0.5	1.5	1.	2.	8.	0.	49.5	8.5	1.	0.5	3.5	1.
12	0.	2.5	1.	0.	8.5	0.	1.5	3.5	0.	0.	1.	0.	1.5	3.5	3.	3.5	0.	55.	10.	0.5	0.5	3.	1.
13	0.	1.	4.	0.	17.5	0.	2.	2.5	0.	0.	0.	0.	0.5	0.5	2.5	1.5	0.	56.	9.	0.5	0.	2.5	0.
14	0.	1.5	2.5	0.	16.	0.	0.	3.5	0.	0.	0.	3.	0.5	1.	0.	1.	0.	57.	8.	3.5	0.5	5.	0.
15	0.	2.	0.5	1.5	9.5	1.	11.5	4.	0.	0.	0.	4.	0.	0.	1.	3.	1.5	55.	5.5	2.5	0.5	0.	0.
16	0.	4.	1.5	0.	11.5	0.	5.	2.5	0.	0.	6.5	5.	1.5	0.5	3.	3.	0.	44.	2.	1.5	0.	6.5	0.
17	0.	1.	2.5	0.	8.	0.5	4.5	6.	0.	0.	8.	4.	0.	2.	2.	5.	0.	45.	2.	0.	0.5	5.	0.
18	0.	0.5	2.	0.	12.	0.	11.5	6.	0.	0.5	1.5	0.5	0.	0.	3.5	2.	0.	49.5	3.5	1.5	0.	6.	0.
19	0.	0.	0.	0.5	18.	0.	1.	2.	0.	0.	0.	0.	0.	3.	2.	2.	0.	60.5	6.5	0.	0.	3.	0.
20	0.	4.	0.	0.5	6.	0.	2.5	1.	0.	0.	0.	1.5	3.5	2.5	2.	2.5	0.	71.5	5.5	1.	0.	0.	0.5
22	0.	2.	0.5	0.5	5.5	0.	3.	0.	0.	0.	0.5	2.	0.	5.	4.	7.5	0.	63.	2.	1.5	0.	0.5	0.
23	0.	2.	0.	0.5	12.5	0.	2.5	4.5	0.	0.	0.	1.5	2.5	0.	1.	3.5	0.	63.	4.	0.5	0.	3.	0.
26	0.	1.5	0.5	0.5	11.	0.	1.	2.	0.	0.	0.	0.	0.	1.5	4.	2.	0.	53.	19.	1.5	0.	1.	0.
27	0.	1.25	0.	0.6	6.8	0.	1.25	0.6	0.	0.	1.25	0.	0.	0.	2.5	3.75	0.	71.25	10.	0.	0.	0.6	0.

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TABLE I—(Continued)

Percentages of tree pollens—Pinhook bog

Foot-level	Abies	Acer	Betula	Carpinus	Carya	Fagus	Fraxinus	Juglans	Juniperus	Larix	Nyssa	Ostrya	Picea glauca	Picea mariana	Pinus banksiana	Pinus strobus	Populus	Quercus	Salix	Tilia	Tsuga	Ulmus	Unknown
28	0.	3.5	0.5	0.	9.	0.	3.5	0.5	0.	0.5	0.5	0.	1.5	3.	2.5	5.	0.	54.	12.	0.	1.	1.	1.5
29	0.	0.	0.	0.	14.	0.	0.5	1.	0.	0.5	0.	0.	1.5	2.	1.	3.5	0.	62.	13.	0.	0.	1.	0.
30	0.	0.5	1.5	0.	20.	1.5	2.	5.5	0.	0.	0.	0.	3.5	0.	3.	0.	0.	48.5	13.	1.5	0.	1.5	0.
31	0.	1.	0.	0.	15.5	5.	0.	1.	0.	0.	0.	0.	1.	0.	1.	5.	0.	48.5	18.5	0.	0.5	2.	0.
32	0.	1.	1.5	0.	19.5	0.	0.	5.5	1.	0.5	0.	0.	0.	1.5	2.	2.	0.	53.5	13.5	0.	0.	2.	0.
33	0.	0.	0.5	0.	10.	1.5	0.	0.5	1.5	0.	0.	0.	3.	4.	2.5	9.	0.	55.	14.	0.	0.	1.5	0.5
34	2.	0.	2.	0.	3.5	0.5	0.	0.5	1.	0.	0.	0.	11.5	10.	6.5	21.5	0.	35.5	10.5	0.	0.	0.	0.5
35	1.5	0.	2.5	0.	5.	0.5	0.	1.	0.	0.	0.	0.	5.	14.	10.	30.5	0.	26.5	5.5	0.	0.	1.	0.
36	0.5	0.5	1.	0.	6.	0.	0.	1.	0.	0.	0.	0.	5.	13.5	19.	41.5	0.	6.5	2.	0.	0.	3.5	0.
37	3.5	0.	6.5	0.	1.5	0.	1.	1.	1.	0.	0.	0.	6.	10.	13.5	25.	0.	24.	2.5	0.	0.	2.5	0.
38	3.5	0.	12.	0.	0.	0.	0.	0.	0.	0.	0.	0.	10.5	9.5	32.5	12.5	0.	16.	1.	0.	0.	1.	0.
39	6.	0.	9.	0.	0.5	0.	0.	0.	1.	0.	0.	0.	12.5	23.5	36.	12.5	0.	10.5	1.	0.	0.	0.5	0.
40	6.	0.	0.5	0.	0.	0.	0.	0.	0.	0.	0.	0.	30.	22.5	11.	22.	0.	6.5	0.5	0.	0.	0.	0.
41	12.5	0.	0.	0.	1.5	0.	0.	1.	1.	1.	0.	0.	41.	23.	3.	11.	0.	8.5	0.	0.	0.	0.	0.
42	12.5	0.	1.	0.	3.	0.	0.	0.	0.	0.	0.	0.	40.	22.5	2.	8.5	0.	9.	0.5	0.	0.	0.	0.
43	4.5	1.5	1.5	0.	2.	0.	0.	0.	0.	0.	0.	0.	32.5	21.5	5.	15.	0.	10.5	0.	0.	0.	0.	0.
44	3.5	0.	0.	0.	0.5	0.	0.	0.	0.	0.5	0.	0.	35.	33.5	2.5	17.5	0.	6.	0.	0.	0.5	0.	0.
45	5.5	0.	0.	0.	0.5	0.	0.	0.5	0.	0.	0.	0.	43.	26.5	2.5	16.5	0.	5.	0.	0.	0.	0.	0.
46	13.	0.	0.	0.	0.	0.	0.	0.5	0.	0.	0.	0.	41.	21.	3.	10.5	0.	10.	0.	0.	0.	0.	0.

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TABLE I—(Continued)

Percentages of tree pollens—Pinhook bog

Foot-level	Abies	Acer	Betula	Carpinus	Carya	Fagus	Fraxinus	Juglans	Juniperus	Larix	Nyssa	Ostrya	Picea glauca	Picea mariana	Pinus banksiana	Pinus strobus	Populus	Quercus	Salix	Tilia	Tsuga	Ulmus	Unknown
47	4.5	0.	0.5	0.	0.	0.	0.	0.	0.	0.	0.	0.	36.	31.5	3.5	18.	0.	3.5	1.	0.	0.	0.	1.5
48	10.5	0.	0.	0.	0.5	0.	0.	0.5	0.	0.	0.	0.	47.5	25.	2.5	7.	0.	6.	0.5	0.	0.	0.	0.
49	7.5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	47.5	25.	2.	13.	0.	5.	0.	0.	0.	0.	0.
50	2.5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	43.	32.5	2.5	19.	0.	1.	0.	0.	0.	0.	0.
51	5.	0.	0.	0.	0.	0.	0.	0.	0.	0.5	0.	0.	44.	28.5	4.	17.	0.	1.5	0.	0.	0.	0.	0.
52	6.5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	40.	25.	3.	23.	0.	2.	0.5	0.	0.	0.	0.
53	5.	0.	0.	0.	0.5	0.	0.	0.5	0.	0.	0.	0.	42.	33.5	1.5	12.	0.	5.5	0.	0.	0.	0.	0.
54	8.	0.	0.	0.	0.5	0.	0.	0.	0.	0.	0.	0.	60.5	20.5	0.5	4.	0.	5.5	0.	0.	0.	0.	0.
55	10.	0.	0.	0.	0.	0.	0.	0.	0.	1.	0.	0.	44.	26.5	3.5	11.5	0.	4.	0.	0.	0.	0.	0.
56	11.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	35.5	31.	5.5	14.5	0.	1.5	0.	0.	0.	0.	0.
57	16.5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	51.5	21.	3.	6.	0.	2.	0.	0.	0.	0.	0.
58	13.5	0.	0.	0.	0.	0.	0.	0.	0.	0.5	0.	0.	62.	17.5	3.5	3.	0.	0.	0.	0.	0.	0.	0.
59	14.	0.	0.	0.	0.	0.	0.	0.	0.	0.5	0.	0.	54.	25.	1.	3.5	0.	2.	0.	0.	0.	0.	0.

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TABLE II

Percentages of tree pollens—Merrillville bog

Foot-level	Abies	Acer	Betula	Carpinus	Carya	Fagus	Fraxinus	Juglans	Juniperus	Larix	Nyssa	Ostrya	Picea glauca	Picea mariana	Pinus banksiana	Pinus strobus	Populus	Quercus	Salix	Tilia	Tsuga	Ulmus	Unknown
¼	0.	2.	0.	0.	6.	0.	0.	4.	0.	0.	0.	0.	6.	4.	4.	32.	0.	32.	2.	0.	0.	6.	2.
1	3.	0.	2.	0.	10.	5.	0.	0.	0.	0.	0.	0.	6.	1.	2.	34.	1.	30.	1.	0.	0.	5.	0.
1½	0.5	7.5	1.5	0.	10.5	7.	0.	2.	0.	0.	2.	0.	3.5	1.5	1.5	21.	2.5	33.5	2.	1.	0.5	2.	0.
2	0.	0.	1.	0.	7.	1.	0.	1.	0.	0.	1.	0.	6.	2.	3.	21.	4.	48.	0.	0.	0.	6.	1.
3	0.	2.	0.	0.	12.	1.	0.	0.	0.	0.	0.	0.	4.	2.	2.	39.	2.	30.	2.	1.	0.	0.	1.
4	1.	0.	1.	0.	12.	0.	0.	0.	0.	0.	1.	0.	3.	2.	1.	30.	6.6	44.	1.	0.	0.	0.	2.
5	0.	4.	0.	0.	8.	1.3	0.	4.	0.	0.	0.	0.	9.3	1.3	4.	22.6	0.	28.	5.3	1.3	0.	0.	4.
6	0.	0.	0.8	0.	11.3	0.	0.	0.8	0.	0.	0.	0.	4.3	7.8	2.6	10.4	0.	47.8	4.3	0.	0.	6.	2.6
7	0.	1.	1.	0.	10.	2.	0.5	3.	0.	0.	0.	0.	0.	5.	4.	4.	0.	55.	0.	0.	3.	10.	2.
8	1.	3.	1.	0.	20.	2.	0.	1.	0.	0.5	1.	0.	0.	2.	3.	4.	0.	50.	2.	0.	1.	7.	3.
9	0.	1.	1.	0.	10.5	3.5	0.5	2.	0.	1.	2.	0.	8.5	1.5	1.5	6.5	1.5	53.	0.5	0.	5.	3.5	0.
10	0.5	3.	0.	0.	6.	1.	0.	3.5	0.	0.	1.	0.	4.	4.	1.	5.	0.	53.	3.	2.	2.	6.	4.
11	0.5	2.5	2.	0.	11.	0.	0.	3.	0.	0.	0.	2.	3.5	0.	1.	1.	0.	66.	3.5	0.	0.	4.	2.
12	0.	3.5	1.5	0.	16.	4.	0.	0.5	0.	0.	3.5	0.	0.	0.5	1.	3.	0.	55.	1.5	0.5	0.	6.	0.5
13	0.5	1.5	2.5	0.5	20.	3.	0.	2.	0.	0.	1.	0.	1.5	2.	0.5	3.	0.	57.5	2.	0.5	0.	1.	0.5
14	0.	3.	3.	0.	16.5	2.	0.	2.5	0.	0.	0.5	0.	2.	2.5	0.	0.5	0.	57.5	1.5	1.	0.	5.5	0.5
15	0.5	2.5	5.5	0.	11.	0.	0.	0.5	0.	0.	0.5	0.	5.	5.5	2.	10.	0.	48.5	3.5	0.	0.	6.	0.5
16	0.	0.	1.	0.	16.5	0.	0.	1.	0.	0.	0.	0.	0.	5.5	2.	4.	0.	60.5	1.5	0.	0.	3.5	0.
17	0.5	0.5	1.	0.	10.5	0.	0.	1.	0.	0.	0.	0.	1.	23.5	0.5	8.5	0.	48.	9.	0.	0.	5.5	0.

TABLE II—(Continued)
Percentages of tree pollens—Merrillville bog

Foot-level	Abies	Acer	Betula	Carpinus	Carya	Fagus	Fraxinus	Juglans	Juniperus	Larix	Nyssa	Ostrya	Picea glauca	Picea mariana	Pinus banksiana	Pinus strobus	Populus	Quercus	Salix	Tilia	Tsuga	Ulmus	Unknown
18	0.	0.	0.5	0.5	9.5	0.	0.	1.	0.	0.	1.	0.5	1.	8.	0.	3.5	0.	60.	10.	0.	0.	4.5	0.
19	0.	0.	3.	0.	7.	0.	0.	0.	0.	0.	0.	0.	3.5	4.5	1.	2.5	0.	71.5	3.	0.	0.	4.	0.
20	0.	1.	0.5	0.	7.	0.	0.	0.	0.	0.	1.	0.	1.5	5.	0.5	5.	0.	70.5	4.	0.	0.	4.	0.
21	0.5	0.5	2.5	0.	0.	0.	0.	0.5	0.	1.	0.5	1.	6.5	10.	0.5	15.	0.	57.	1.5	1.	0.5	2.	0.
21½	0.	0.	3.	0.	4.	0.	0.	0.5	0.	0.	0.	0.	0.5	9.	1.5	4.	0.	69.	4.	0.	0.5	2.5	0.
22	0.	0.5	0.5	0.5	6.	0.	0.	0.5	0.	1.	0.5	0.5	1.5	5.	0.	1.	0.	72.	6.	1.	0.	5.	0.5
23	2.	0.	3.	0.	9.5	0.	0.	1.5	0.5	0.	0.	0.5	5.5	11.5	2.5	9.	0.	49.	1.5	0.	0.5	3.	1.
24	9.5	0.	8.5	0.	2.5	0.	0.	0.	0.	3.	0.	4.	19.	16.	1.	16.	0.	19.	0.	0.	0.	1.	0.
25	14.	5.	1.	0.	2.5	0.	0.	0.	0.	2.5	0.	0.	46.5	23.	0.5	3.5	0.	6.	0.	0.	0.	0.	0.
26	23.5	0.	1.	0.	0.	0.	0.	0.	0.5	0.5	0.	0.	43.	15.5	0.5	5.5	0.	0.	0.	0.	0.	0.5	0.
27	6.5	0.	0.	0.	0.5	0.	0.	0.	0.	1.5	0.	0.	29.5	43.	2.5	13.	0.	0.	0.	0.	0.	0.5	0.
28	10.5	0.	0.	0.	0.	0.	0.	0.	0.5	0.	0.	0.	35.5	39.5	0.5	12.5	0.	0.	0.	0.	0.	0.	1.
29	3.5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	53.	37.	0.	4.	0.	1.	0.	0.	0.	0.	0.
30	11.5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	48.	26.5	0.	11.	0.	3.	0.	0.	0.	0.	0.
31	6.5	0.	1.	0.	0.5	0.	0.	0.	0.	0.	0.	0.	55.5	29.	0.5	3.	0.	4.	0.	0.	0.	0.	0.
32	9.5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	65.5	21.	2.	2.	0.	0.	0.	0.	0.	0.	0.
33	7.5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	66.5	21.5	2.	2.5	0.	0.	0.	0.	0.	0.	0.
34	12.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	60.	14.	4.	6.	0.	4.	0.	0.	0.	0.	0.

GROWTH-RAINFALL TREND COEFFICIENTS SHOWN BY SIX SPECIES OF HARDWOODS IN BROWN COUNTY, INDIANA

By RAY C. FRIESNER

In an earlier paper (1) it has been shown that when rainfall, for any period with which radial tree growth shows a significant correlation, is conspicuously less than for the corresponding period of the previous year, decrease in tree growth occurs in a higher percentage of individuals than the percentage of trees which show increased radial growth during years when the rainfall shows conspicuous increases for the same periods. Decreased rainfall was accompanied by decreased growth in 62-82% of the years while increased rainfall was accompanied by increased radial growth in 50-72% of the years. During years when there was 90-100% agreement amongst individual trees, increase in radial growth accompanied increase in rainfall and decrease in radial growth accompanied decrease in rainfall for nearly all month combinations.

The above results were obtained from trees on sites subject, because of topography, to minimum amounts of run-off. The present study was made with a view to pursuing the problem further and especially to determine the possible effect of a site where run-off, because of steep slopes, is certain to be high. Six species were availabl for study, viz., *Carya ovata* (4 sections), *C. glabra* (5 sections), *Acer saccharum* (7 sections), *Liriodendron tulipifera* (4 sections), and *Sassafras albidum* (3 sections). The study was made from sections cut from stumps following logging operations and the individuals were chosen from steep slopes of ravines on the ridge forming the divide between Bean Blossom Creek and Salt Creek, about 1.5 mi. east of Bear Wallow in Brown County, Indiana.

METHODS

Ring width measurements were made under 10x magnification on 4-6 equidistant radii on each section. Growth-rainfall trend coefficients for 23 different month combinations and individual trend coefficients comparing each individual with each other individual were prepared. Relationship between growth changes and rainfall

changes was determined for various degrees of rainfall change, e.g. (1) all rainfall changes; (2) changes amounting to 10% or more of the normal-expected rainfall for the particular combination of months; (3) changes of 20% or more; (4) changes of 30% or more; (5) changes of 40% or more. The trend coefficients for increases in rainfall only were compared with those for decreases only and both of these were compared with trend-coefficients for all rainfall changes.

Rainfall data used were those recorded at the Columbus (Indiana) station of the U. S. Weather Bureau. This station is about 18 miles from the location of the trees used for study. It is to be regretted that no closer source of data was available.

RESULTS

Growth-rainfall Trend Coefficients

All Rainfall Changes. Growth-rainfall trend coefficients, i.e., the percentage of agreements in sign shown in comparing year-to-year changes in ring growth with year-to-year changes in rainfall for various month combinations (4), are shown in table I. From the table it will be seen that *Carya ovata* shows the highest trend coefficient (68%) when growth is compared with rainfall for May-July while *C. glabra* shows equal but low trend coefficients (55%) for three different month combinations, viz., May-July, and the 12-month periods, August-July, and June-May. *Acer saccharum* shows a low trend coefficient (55%) for the early summer period, May-August, and for the late spring period May-June. *Liriodendron tulipifera* shows its highest trend coefficient (58%) for the 12-month period, July-June. *Fraxinus americana* shows its highest trend coefficient (67%) for the late spring-early summer period, April-July. *Sassafras albidum* shows its highest trend coefficient (51%) for three different month combinations, viz., the calendar year, the 12-month period August-July, and the 15-month period June-August. The trend coefficient in this species is so low that it may be considered to be of no significance.

All Rainfall Changes Compared with Ten Percent or Greater Changes. In table II trend coefficients for all rainfall changes are compared with those in which the changes in rainfall are 10% or more, 20% or more, 30% or more, and 40% or more of normal. The comparison is based only upon the month-combinations showing high-

est trend coefficients for all rainfall changes. With a few minor exceptions it will be seen that the trend coefficients are progressively higher with increased percentage of rainfall change.

Table II further compares all changes of each degree with increases only and with decreases only. In all species studied except *Carya glabra* the trend coefficients based upon the decreases in rainfall only are higher than those based upon increases only. It would thus appear that these species (except *C. glabra*) show a greater sensitivity to decreases in rainfall than they do to increases and that their reaction is greater with increased degree of change. In nearly all cases the trend coefficients progressively increase with increased degree of rainfall change whether all changes, increases only, or decreases only are considered.

Carya glabra consistently shows higher trend coefficients when the rainfall changes considered are increases only than when they are all changes or decreases only. It would thus appear that this species is more readily responsive to increases in rainfall than to decreases. McInteer (3) found no significant differences of correlation between growth and rainfall in years of reductions and years of increases in the case of *Pinus virginiana* and *P. taeda*.

In Marshall county study (1), where run-off was undoubtedly much less, a greater response to decreases in rainfall than to increases was also shown.

Agreement of Individuals with Each Other

Table III shows the range of and the average trend coefficients (percentage of agreements) when radial growth of each individual tree is compared with each other individual tree. It will be noted that in no case is the percentage of agreements between individuals of the same species appreciably higher than the percentage of agreements between individuals of one or more other species. For example, individuals of *Carya ovata* show an average agreement of 61% with each other and of 62% when compared with individuals of *Fraxinus americana*. Similarly, *Fraxinus americana* shows a slightly higher agreement with individuals of *C. ovata* than it does with individuals of its own species. *Liriodendron tulipifera* is the only species in which there is a higher percentage of agreement amongst its own individuals than when its individuals are compared with those of all other species.

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While the percentage of agreements of certain individuals with other individuals of the same species is high (e.g., one individual of *Carya ovata* agreed with another individual of the same species in 89% of the years), the opposite is also true. One individual of *Carya ovata* showed as low as 22% of the years in agreement with an individual of *Acer saccharum*. The highest percentage of agreement shown by any individual of any particular species with any other individual is not necessarily with some other individual of the same species. For example, the highest percentage of agreement of any individual of *Carya glabra* with any other individual of the same species is 70% while one individual of this species shows agreement with an individual of *Fraxinus americana* in 77% of the years. At the same time the highest percentage of agreement between any individual of *Fraxinus americana* and any other individual is with another individual of *F. americana*. The highest percentage of agreement of any individual of *Acer saccharum* with any other individual of the same species is 75% while the same individuals of *Acer saccharum* show agreement with an individual of *Carya ovata* in 78% of the years and with an individual of *Fraxinus americana* in 77% of the years. Ranges of agreements as well as averages are given in table III. All of this would seem to indicate that the particular site of the individual tree plays an important part in relation to growth-rainfall trend coefficients, especially in areas where variations in steepness of slope may materially affect the amount of rainfall retained by the soil. Other factors, particularly the nearness of other trees and the character of the forest canopy, may also play a vital role. We are thus dealing with a complex of variables and the degree of relationship of any one of them with growth will be modified by the others.

Hansen (2) has found average agreements amongst *Pinus ponderosa, Larix occidentalis* and *Pseudotsuga mucronata* in percentages of years ranging from 46% to 51%. His figures do not reveal the percentages of agreements of individuals of the same species amongst themselves.

SUMMARY AND CONCLUSIONS

1. *Carya ovata* shows its highest growth-rainfall trend coefficient for the period, May-July.

2. *C. glabra* shows its highest trend coefficient for the periods, May-July, August-July and June-May.

3. *Acer saccharum* shows its highest trend coefficient for the periods, May-August and May-June.

4. *Lirodendron tulipifera* shows its highest trend coefficient for the 12-month period, July-June.

5. *Fraxinus americana* shows its highest trend coefficient for the period, April-July.

6. *Sassafras albidum* shows trend coefficients so low that they are of no significance.

7. With but few exceptions trend coefficients for all species increase in percentage with increased percentage of rainfall change.

8. All species except *C. glabra* show higher trend coefficients when rainfall decreases only are considered than when rainfall increases only are considered.

9. *C. glabra* shows higher trend coefficients when rainfall increases only are considered than when rainfall decreases only are considered.

10. When any individual tree is compared with any other individual tree, the highest percentage of agreement is as likely to be with an individual of a different species as with an individual of the same species.

11. *Liriodendron tulipifera* is the only species which shows a higher average percentage of agreements with individuals of its own species than with individuals of other species.

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TABLE I

Trend coefficients of each species for each month-combination rainfall period

Rainfall Periods	Carya ovata	Carya glabra	Acer saccharum	Liriodendron tulipifera	Fraxinus americana	Sassafras albidum
1. Calendar Year	54	49	52	51	61	(51)
2. Nov.-Oct.	58	51	50	52	60	45
3. Oct.-Sept.	56	50	54	54	61	50
4. Sept.-Aug.	58	49	52	52	59	46
5. Aug.-July	62	(55)	52	53	61	(51)
6. July-June	56	51	50	(58)	60	48
7. June-May	51	(55)	49	53	57	50
8. June-Aug.-Aug.	58	53	54	55	64	(51)
9. Mar.-Aug.	56	48	52	51	64	45
10. Apr.-Aug.	59	50	52	51	65	47
11. May-Aug.	62	48	(55)	51	61	50
12. June-Aug.	61	53	54	49	59	47
13. Mar.-July	58	50	53	53	66	46
14. Apr.-July	64	52	53	48	(67)	47
15. May-July	(68)	(55)	54	49	64	45
16. June-July	62	50	54	49	61	50
17. Mar-June	55	51	50	52	61	41
18. Apr.-June	58	49	48	54	65	48
19. May-June	65	49	(55)	49	66	46
20. Mar.-May	50	51	51	54	60	49
21. Apr.-May	51	53	49	56	61	49
22. June	63	46	50	48	60	46
23. Jan.-Aug.	54	49	52	56	59	45

TABLE II

Trend coefficients considering (1) all rainfall changes, (2) changes amounting to 10% or greater of normal, (3) 20% or greater, (4) 30% or greater, (5) 40% or greater; and further comparing (6) all changes of each degree with (7) increases only and with (8) decreases only.

Tree Species		Carya ovata	Carya glabra	Acer saccharum	Liriodendron tulipifera	Fraxinus americana	Sassafras albidum
		(15)	(5)	(11)	(6)	(14)	(8)
Rainfall-Periods		May-July	Aug.-July 12 mo.	May-Aug.	June-May 12 mo.	April-July	June-Aug.-Aug. 15 mo.
All rainfall changes	All Changes	68	55	55	58	67	51
	Incr. only	67	58	55	56	63	51
	Decr. only	71	54	58	61	75	52
10% or greater changes	All changes	70	54	55	55	68	49
	Incr. only	67	62	54	56	64	51
	Decr. only	74	53	61	52	75	51
20% or greater changes	All changes	73	55	60	59	72	54
	Incr. only	68	61	54	57	65	58
	Decr. only	80	51	65	62	83	56
30% or greater changes	All changes	75	59	58	54	76	58
	Incr. only	68	64	57	58	69	67
	Decr. only	79	*	61	60	84	52
40% or greater changes	All changes	77	64	58	69	80	56
	Incr. only	72	70	53	65	64	*
	Decr. only	78	*	65	75	89	*

* No rainfall changes of this magnitude occurred for this month-combination.

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TABLE III

Trend Coefficients: Average percentage of Correlation of each Species with each Other Species

	Carya ovata		Carya glabra		Acer saccharum		Liriodendron tulipifera		Fraxinus americana		Sassafras albidum	
	Range	Av.	Range	Av.	Range	Av.	Range	Av.	Range	Av.	Range	Av.
Carya ovata	52-89	(61)	42-76	52	22-78	53	35-63	46	35-80	62	39-68	47
Carya glabra	42-76	52	40-70	(50)	30-73	51	33-70	51	40-77	55	41-66	53
Acer saccharum	22-78	53	30-73	51	27-75	(50)	24-61	49	23-77	52	39-63	51
Liriodendron tulipifera	35-63	46	33-70	51	24-61	49	40-65	(56)	32-59	49	39-72	55
Fraxinus americana	35-80	62	40-77	55	23-77	52	32-59	49	43-83	(61)	40-65	51
Sassafras albidum	39-68	47	41-66	53	39-63	51	39-72	55	40-65	51	45-51	(47)

THE EFFECT OF PRECIPITATION ON ANNULAR-RING GROWTH IN THREE SPECIES OF TREES FROM BROWN COUNTY, INDIANA

By CHESTER W. MILLER

The present study is an attempt to determine what rainfall periods show the highest degree of correlation with growth in three species of deciduous trees from Brown County, Indiana, and to determine which area of the tree, i.e., the top or the bottom, gives the closest growth-rainfall correlation.

Fuller (3) has shown that there is a close correlation between precipitation for the calendar year in Illinois and increase in diameter in *Quercus borealis maxima* as shown by thickness of its annual growth rings. Kleine, Potzger, and Friesner (5), using 11 trees of *Quercus alba,* 17 of *Quercus montana,* 16 of *Quercus velutina,* and 9 of *Quercus borealis maxima,* found a correlation between annual growth and rainfall for the months June, July and August. This work, as in the present study, was done on sites with considerable relief and hence subject to excessive run-off. Friesner and Friesner (1), from work done with *Quercus borealis maxima, Quercus alba, Fraxinus americana, Acer saccharum, Carya cordiformis,* and *Liriodendron tulipifera,* found that the highest degree of correlation for most specimens was with rainfall for either June-August or the single month of June, but individual exceptions were found in which the highest correlation was with other rainfall periods.

MATERIALS AND METHODS

Sections were cut from stumps and further up the trunks of 20 specimens of *Quercus alba* L., 10 specimens of *Quercus velutina* Lam., and 3 specimens of *Fraxinus american* L. Four pairs of sections of *Quercus velutina* and 6 pairs of sections of *Quercus alba* were taken from the same trees in order to determine what degree of agreement there is between the top area and the bottom area of the same tree. All specimens grew in the knobs area of Brown County, Indiana, 8 miles east of Nashville, just north of Indiana highway 46.

Rainfall data were secured from the U. S. Weather Bureau station located in Columbus, approximately 10 miles east of the forest in which the trees grew. Rainfall behavior charts were prepared for the calendar year; the vegetative year beginning November 1 and ending October 31; the water year (2) beginning October 1 and ending September 30; for the 12-month periods: September-August, August-July, July-June, June-May; the 15-month period (6): June of one year through August of next; and shorter periods: March-August, April-August, May-August, June-August, March-July, April-July, May-July, June-May, March-June (7), April-June, May-June, March-May (6), April-May, June, and January-August.

Growth as shown by annual ring width was measured along four equidistant radii of each section. Measurements were made under a 10X magnifier and to the nearest quarter millimeter, the scale being graduated in one-half millimeters. Yearly behavior charts for each tree were prepared from the sums of the measurements of the 4 radii of each section. Glock (4) states that the best record of the variation of the effectiveness of the growth factors in permitting the formation of secondary wood is obtained by averaging the measurements of six radii. Fuller (3) used the averages of three radii in his work with oak in Illinois. Friesner and Friesner (1) used the sum of the measurements of eight radii. Lodewick, as reported by Friesner and Friesner (1), found no striking differences between results obtained from four radii and from only one radius on the same tree.

Growth-rainfall trend coefficients (1), i.e., the proportion of agreement in sign of the year-to-year changes between rainfall and growth for the different month combinations, individual trend coefficients comparing each individual with each other individual, trend coefficients comparing annual growth of the top area with the bottom area of the same tree, growth-rainfall trend coefficients comparing the annual growth of the top area with the annual growth of the bottom area of the same species, and growth-rainfall trend coefficients comparing all decreases with all increases and further comparing both of these with all changes of the optimum and next best rainfall periods for each species, were prepared and are presented in the tables.

OBSERVATIONS AND RESULTS

GROWTH-RAINFALL TREND COEFFICIENTS

The rainfall periods showing the highest growth-rainfall trend coefficients for all rainfall changes, changes amounting to 10% or greater of normal expected for the period, 20% or greater, 30% or greater, and 40% or greater, are shown in table I. It will be observed that the highest trend coefficients in the three species studied are for the period June-August in *Quercus alba* (20 specimens) while the period May-August is second highest. *Quercus velutina* (10 specimens) has the highest trend coefficients for the period June-July, while the period June-August is a close second. In the case of *Fraxinus americana* (3 specimens), the period May-August shows the highest trend coefficients, while the period June-August is second highest. There are so few sections of *Fraxinus americana* available that these data do not warrant further definite conclusions.

Upon closer observation of table I, it will be seen that the period June-August shows high trend coefficients in all three species. In *Quercus alba* it shows the highest trend coefficient, and in *Quercus velutina* and *Fraxinus americana* it shows the second highest trend coefficient. This result is in agreement with previous research carried on in the Butler University botanical laboratory (5) with four species of *Quercus* from a similar area in Indiana. This evidence indicates a close agreement between annual growth and rainfall for the period June-August. In each species studied, it will be noted (table I) that in general, as the percentage of change in rainfall increases, the trend coefficients also increase. There are, however, exceptions in the case of the changes amounting to 40% or greater of the normal expected rainfall. This may be due in part to the fact that there were so few times when rainfall changes were of this magnitude during a particular period. Table V shows the trend coefficients for all changes, changes amounting to 10% or greater of the normal expected for the period, 20% or greater, 30% or greater, and 40% or greater, and further compares all changes of each degree with increases only and decreases only. In nearly all cases the trend coefficients based upon decreases only for the optimum rainfall periods are higher than the trend coefficients based upon increases only or upon all rainfall changes.

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Table II gives the trend coefficients of each species with each other species and of different individuals of each species with each other. *Quercus alba* has a range of 62%-93% and an average of 79% agreement with different individuals of itself; a range of 54%-92% and an average of 70% agreement with different individuals of *Fraxinus americana;* and a range of 58%-92% and an average of 72% agreement with different individuals of *Quercus velutina.* *Fraxinus americana* has a range of 73%-85% and an average of 77% agreement with itself; a range of 54%-92% and an average of 70% agreement with Quercus alba; and a range of 58%-79% and an average of 66% agreement with *Quercus velutina.* *Quercus velutina* has a range of 53%-94% and an average of 70% agreement with itself; a range of 58%-79% and an average of 66% agreement with *Fraxinus americana;* and a range of 58%-92% and an average of 72% agreement with *Quercus alba.* The highest average percentage of agreement (79%) is found when different individuals of *Quercus alba* are compared with each other, while the lowest percentage of agreement (66%) is found when individuals of *Quercus velutina* are compared with those of *Fraxinus americana.* It is thus seen that both *Fraxinus* and *Q. alba* show higher average percentages of agreements amongst individuals of their own species than with individuals of a different species. *Quercus velutina,* on the other hand, shows a higher percentage of agreements with individuals of *Q. alba* than with individuals of its own species.

Agreements Between Top and Bottom Sections

Table III gives the trend coefficients showing the percentage of agreements between sections taken from just above the top logs and from the top of the stumps of the same trees of *Quercus alba* and *Quercus velutina.* The average percentage of agreement between the top areas and the bottom areas of the same trees for *Quercus velutina* is 82%, while that for *Q. alba* is 80%. The highest percentage of agreement between the top area and the bottom area of any single individual of *Quercus velutina* is 86%, while the lowest percentage in the same species is 76%. In the case of *Quercus alba,* the highest percentage of agreement between the top area and the bottom area of any single individual is 87%, while the lowest percentage is 71%.

The periods showing the highest growth-rainfall trend coefficients

(averages) of all the top sections and of all the bottom sections when the rainfall changes are: any change, 10%, 20%, 30%, and 40% or greater of the normal expected for the period are shown in table IV. It will be seen that the highest trend coefficients for all the top and all the bottom sections of *Quercus alba* is for the period June-August. In the case of *Quercus velutina,* the period June-August shows the highest trend coefficients for all the top sections, while the period June-July shows the highest trend coefficients for all the bottom sections. It may also be observed that in general the trend coefficients for both tops and bottoms increase with increase in the degree of rainfall changes. The bottom sections of *Quercus velutina,* however, do not behave in this manner except in the periods May-August and the 15-month period, June of one year through August of the next. In both *Quercus alba* and *Quercus velutina,* the top sections give higher trend coefficients between annual growth and annual rainfall than do the bottom sections. This would seem to indicate that annual growth in *Quercus alba* and *Quercus velutina* is more sensitive to rainfall changes in the top area than in the bottom area.

SUMMARY AND CONCLUSIONS

1. *Fraxinus americana* shows highest growth rainfall trend coefficients for the periods May-August and June-August; *Quercus alba* for the rainfall periods June-August and May-August; and *Quercus velutina* for the periods June-July and June-August.

2. With but few exceptions, growth-rainfall trend coefficients increase with increase in degree of rainfall change.

3. When annual growth of individuals of each species and of different species is compared, the highest percentage of agreement is shown between individuals of the same species except in *Quercus velutina.* *Q. velutina* shows higher average agreement with *Q. alba* than amongst individuals of its own species.

4. The average trend coefficients between growth in the top area and in the bottom area of the same trees of *Quercus velutina* is 82%, while the average for *Q. alba* is 80%.

5. In both *Quercus alba* and *Q. velutina,* the top areas give higher growth-rainfall trend coefficients than do the bottom areas. This would appear to indicate that annual growth in the top area of these species is more sensitive to rainfall changes than annual growth in the bottom areas.

6. *Fraxinus americana* shows higher growth-rainfall trend coefficients when decreases in rainfall only are considered than when increases only are considered.

7. *Quercus alba* shows higher growth-rainfall trend coefficients when decreases in rainfall only are considered than when increases only are considered except in the case of 40% or greater rainfall changes.

8. *Quercus velutina* shows higher growth-rainfall trend coefficients when increases in rainfall only are considered than when decreases only are considered, when comparison is based upon lower degrees of rainfall change, but the reverse is true when comparison is based upon higher degrees of rainfall change.

ACKNOWLEDGMENTS

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TABLE I

Trend coefficients (averages) when rainfall changes are: Any change, 10%, 20%, 30%, and 40% of the normal expected for the period.

Species	Rainfall periods showing highest trend coefficients for all rainfall changes	Trend coefficients—Average of all individuals Rainfall changes—Percentage of normal				
		All	10%	20%	30%	40%
Fraxinus americana	(1) May-August (4 months)	68	75	84	87	83
	(2) June-August (3 months)	60	65	68	70	73
Quercus alba	(1) June-August (3 months)	75	76	79	81	83
	(2) May-August (4 months)	71	76	77	77	85
Quercus velutina	(1) June-July (2 months)	70	72	76	78	79
	(2) June-August (3 months)	70	74	75	77	74

TABLE II

Trend coefficients: Average trend coefficient of each species with each other species

Species	Fraxinus americana		Quercus alba		Quercus velutina	
	Range	Av.	Range	Av.	Range	Av.
Fraxinus americana	73-85	77	54-92	70	58-79	66
Quercus alba	54-92	70	62-93	79	58-92	72
Quercus velutina	58-79	66	58-92	72	53-94	70

TABLE III

Trend coefficients: Showing the percentage of agreements of top and bottom areas of the same tree with each other

Tree No.	Quercus velutina Section Nos.	% of Agreement	Tree No.	Quercus alba Section Nos.	% of Agreement
1	21 and 24	76	5	22 and 23	87
2	25 and 26	81	6	27 and 28	84
3	34 and 35	86	7	29 and 30	71
4	36 and 37	83	8	32 and 33	80
			9	38 and 39	82
			10	40 and 41	78
Average		82			80

TABLE IV

Trend coefficients (averages) of the top area and the bottom area of the same trees when rainfall changes are: any change, 10%, 20%, 30%, and 40% of the normal expected for the period.

Species	Rainfall periods showing highest trend coefficients for all rainfall changes		Trend coefficients Rainfall changes—Percentage of Normal				
			All	10%	20%	30%	40%
Quercus alba (Tops)	(1) June-August	(3 months)	78	80	82	83	85
	(2) June-July	(2 months)	75	75	81	81	82
	(3) May-August	(4 months)	69	79	77	78	84
	(4) May-July	(3 months)	70	72	79	80	85
	(5) June	(1 month)	71	71	70	70	77
Quercus alba (Bottoms)	(1) June-August	(3 months)	71	74	76	80	81
	(2) May-August	(4 months)	69	73	77	76	87
	(3) June-July	(2 months)	72	72	74	78	77
	(4) May-July	(3 months)	71	69	78	76	80
	(5) April-July	(4 months)	68	70	70	71	78
Quercus velutina (Tops)	(1) June-August	(3 months)	75	75	76	80	80
	(2) June-July	(2 months)	71	77	77	80	84
	(3) May-July	(3 months)	71	75	75	75	80
	(4) June	(1 month)	74	76	70	72	75
	(5) May-August	(4 months)	67	76	71	71	80
Quercus velutina (Bottoms)	(1) June-July	(2 months)	69	67	80	76	74
	(2) June-August	(3 months)	65	72	73	74	70
	(3) January-August	(8 months)	77	66	67	90	75
	(4) May-August	(4 months)	59	66	66	67	79
	(5) June of 1 year through August of next	(15 months)	61	62	62	66	73

TABLE V

Trend coefficients considering: (1) all rainfall changes, (2) changes amounting to 10% or greater of normal, (3) 20% or greater, (4) 30% or greater, (5) 40% or greater; and further comparing (6) all changes of each degree, with (7) increases only, and with (8) decreases only.

Tree Species		Fraxinus americana		Quercus alba		Quercus velutina	
Rainfall Periods		May-Aug. 4 months	June-Aug. 3 months	June-Aug. 3 months	May-Aug. 4 months	June-July 2 months	June-Aug. 3 months
All Rainfall Changes	All changes	68	60	75	71	70	70
	Incr. only	59	53	71	70	76	73
	Decr. only	76	71	76	71	68	72
10% or Greater Changes	All changes	75	65	76	76	72	74
	Incr. only	67	54	74	74	75	78
	Decr. only	85	73	79	80	73	71
20% or Greater Changes	All changes	84	68	79	77	76	75
	Incr. only	64	56	75	77	75	78
	Decr. only	94	76	81	80	80	75
30% or Greater Changes	All changes	87	70	81	77	78	77
	Incr. only	63	65	91	75	74	83
	Decr. only	98	82	82	81	84	73
40% or Greater Changes	All changes	83	73	83	85	79	74
	Incr. only	80	65	85	87	76	88
	Decr. only	91	90	82	85	84	76

POLYPLOIDY AMONG PLANT SPECIES EXTRANEOUS IN INDIANA[1]

By FRANCES I. SCOTT

This study was undertaken for the purpose of determining whether there is any relationship between polyploidy and geographic distribution with special reference to species extraneous in a given area. It has been maintained that a more rigorous habitat tends to produce polyploids, that plants which are on the limits of their geographic distribution in a given area should exhibit a high degree of polyploidy since they are on one of the extremes of their habitat range, (4). Since polyploids (particularly tetraploids) usually exhibit a greater vigor and adaptability than do diploids, it has seemed a natural deduction that diploid species might tend to give rise to polyploid races where the habitat had become more rigorous than the optimum for that species. To determine whether or not such a relationship exists among extraneous Indiana species, all such extraneous species which have been studied cytologically were tabulated.

MATERIAL

The material for this study was taken from various sources. The extraneous species were determined from distributions given in Deam's *Flora of Indiana* (8) and from the State Flora Index maintained by the Botany Department of Butler University. The chromosome numbers were chiefly obtained from the following published sources: Tischler's *Tabulae Biologicae,* (22, 23), Gaiser's *List of Chromosome Numbers in Angiosperms* (12), Darlington's *Chromosome Atlas of Cultivated Plants* (6), and the *Merton Catalogue* (17, 19). Chromosome numbers of additional species were found in the current botanical literature. Material covering the fields of cytogeography, cytology and genetics was taken from the literature which is cited in the bibliography.

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[1] A portion of a thesis submitted in partial fulfillment of the requirements for the graduation honor Magna cum Laude, Department of Botany, Butler University.

Only those extraneous species of the Indiana flora for which chromosome numbers could be found in the literature are included in this study. In some cases, the particular species has not been studied cytologically, but if the other related species of that genus showed a consistent polyploid condition, the species was tabulated as polyploid. Such species are listed in Table I as probably polyploid by the symbol "p.p.." The data utilized in this study are summarized in the following tables.

TABLE I

Indiana extraneous species and polyploidy

| Species | General distribution outside Indiana Compass Directions | | | | | | | | Ploidy |
	W	NW	N	NE	E	SE	S	SW	
Agave virginica				x	x	x	x	x	2n
Hymenocallis occidentalis							x	x	p.p.
Asclepias meadii	x	x	x						2n
variegata				x	x	x	x		2n
Myosotis laxa			x	x			x		4n
micrantha			x	x					4n
virginica v. macrosperma					x	x	x		4n
Campanula uliginosa			x	x					2-4-6n
Lonicera canadensis		x	x	x	x				2-4n
japonica				x	x	x	x		2n
Viburnum affine		x						x	2n
molle	x	x					x	x	2n
pubescens v. deamii							x	x	2n
Stellaria pubera				x	x	x	x		p.p.
Ambrosia bidentata	x						x	x	2n
Antennaria fallax			x			x	x	x	12n
solitaria			x	x	x	x	x		2n
Aster furcatus							x	x	2n
macrophyllus			x	x	x	x			2n
missouriensis v. thyrsoidea	x						x	x	2n
ptarmicoides	x		x	x				x	2n
sericeus			x	x		x	x	x	2n
vimineus			x	x	x	x	x	x	2n
Crepis capillaris				x	x				2n
Hieracium longipilum			x	x				x	3-4-5n
Senecio glabellus						x	x	x	4n
vulgaris		x	x	x	x	x			4n
Silphium laciniatum v. robinsonii						x	x		2n
Solidago erecta				x	x	x	x	x	2n
graminifolia v. media		x	x					x	2n
graminifolia v. remota		x							2n

TABLE I—(Continued)

Indiana extraneous species and polyploidy

Species	General distribution outside Indiana								
	W	NW	N	NE	E	SE	S	SW	Ploidy
rugosa v. celtidifolia						x	x	x	2n
sphacelata						x	x	x	2n
squarrosa			x	x	x	x			2n
Arabis patens			x	x	x	x	x	x	4n
Dentaria heterophylla			x	x	x	x	x		2n
multifida				x	x	x	x		2n
Leavenworthia uniflora						x	x	x	6n
Carex canescens v. disjuncta			x	x					6n
canescens v. subloliacea		x	x	x					8n
gravida v. lunelliana	x	x							p.p.
howei			x			x	x	x	6n
incomperta			x	x	x	x	x	x	5n
laricina			x	x	x				p.p.
mesochorea			x	x	x	x	x		p.p.
richii			x	x	x	x			8n
seorsa			x	x	x	x	x		p.p.
Carex tonsa	x	x	x	x	x	x	x		p.p.
Cyperus dentatus			x	x	x	x			4n
acuminatus	x	x				x	x	x	4n
Eleocharis robbinsii			x	x	x				p.p.
Eriophorum spissum			x	x	x				2n
Dipsacus sylvestris			x	x	x	x			2n
Vaccinium aboreum				x	x	x	x	x	2-4n
stamineum			x	x	x	x	x		2n
Euphorbia heterophylla	x	x				x	x	x	8n
Agropyron pauciflorum	x	x	x	x	x				4n
repens	x	x	x	x	x			x	4-6n
subsecundum	x	x	x	x	x				4n
Agrostis elliottiana			x	x		x	x	x	p.p.
palustris	x	x	x	x	x				p.p.
Alopercurus aequalis	x	x	x	x	x				2n
pratensis	x	x	x	x	x	x			4n
Ammophila breviligulata			x	x	x				4n
Andropogon elliottii					x	x	x	x	4n
virginicus			x	x	x	x	x	x	4n
Anthoxanthum odoratum			x	x	x	x	x	x	2-4n
Arrhenatherum elatius	x	x	x	x	x	x	x		4n
Bromus brizaeformis	x	x	x	x	x				2n
ciliatus	x	x	x	x	x	x		x	2-4n
kalmii		x	x	x					2n
mollis	x	x	x	x	x				4n

TABLE I—(Continued)

Indiana extraneous species and polyploidy

| Species | General distribution outside Indiana | | | | | | | | |
| | | | Compass Directions | | | | | | |
	W	NW	N	NE	E	SE	S	SW	Ploidy
Calamagrostis canadensis	x	x	x	x	x	x			4-6-8n
inexpansa	x	x	x	x					4-6n
longifolia	x	x	x						4-6n
Cynodon dactylon			x	x	x	x	x	x	4n
Elymus riparius			x	x	x				4n
virginicus v. australis	x			x	x	x	x	x	4n
virginicus v. glabriflorus	x			x	x	x	x	x	4n
virginicus v. submuticus			x	x	x	x	x	x	4n
Festuca ovina	x	x	x	x	x				2-8-10n
Glyceria acutiflora			x	x	x				4n
borealis	x	x	x	x					4n
canadensis		x	x	x	x				4n
grandis	x	x	x	x	x	x			4n
pallida	x	x	x	x	x				4n
Hierochloe odorata	x	x	x	x					4n
Holcus lanatus	x	x		x	x	x	x	x	2n
Hordeum jubatum	x	x	x	x	x	x	x		2-4n
nodosum	x	x		x			x		2-4-6n
Hystrix patula v. bigeloviana	x	x	x	x				x	4n
Koeleria cristata	x	x	x	x				x	4n
Leptochloa filiformis				x	x	x	x	x	2n
panicoides							x	x	2n
Leptoloma cognatum	x	x		x	x	x	x	x	4n
Lolium perenne	x	x	x	x	x				2-3-4n
Melica mutica	x			x	x	x		x	2n
nitens	x	x		x	x			x	2n
Milium effusum		x	x	x					4n
Muhlenbergia mexicana	x	x	x	x	x	x		x	4n
Panicum anceps			x	x	x	x	x	x	4n
ashei			x	x	x	x	x	x	2n
bicknellii			x	x	x	x		x	2n
boscii	x	x		x	x	x	x	x	2n
boscii v. molle	x	x		x	x	x	x	x	4n
commutatum	x		x	x	x	x	x	x	2n
depauperatum v. psilophyllum		x	x	x	x				2n
mattamuskeetense				x	x	x			2n
microcarpon	x		x	x	x	x	x	x	2n
oligosanthes	x	x		x	x	x	x	x	2n
pseudopubescens	x	x	x	x	x	x	x		2n
sphaerocarpon	x		x	x	x	x	x	x	2n
subvillosum	x	x	x	x					2n

TABLE I—(Continued)

Indiana extraneous species and polyploidy

| Species | | General distribution outside Indiana | | | | | | | |
| | | | Compass Directions | | | | | | |
	W	NW	N	NE	E	SE	S	SW	Ploidy
tsugetorum		x	x	x	x	x			2n
verrucosum			x	x	x	x			2n
xalapense	x					x	x	x	2n
yadkinense				x	x	x			2n
Paspalum circulare					x	x	x	x	2-4n
fluitans						x	x	x	2-4n
stramineum	x	x	x					x	2-4n
Phalaris arundinacea	x	x	x	x	x	x			2n
Phragmites communis	x	x	x	x		x		x	4-8n
Poa alsodes		x	x	x	x				4n up
autumnalis	x		x	x	x	x	x	x	4n up
chapmaniana	x	x			x	x	x	x	4n up
cuspidata				x		x	x		4n
languida		x	x	x	x				4n up
Poa nemoralis		x	x	x	x				4-6-8n
paludigena		x	x	x					4n up
palustris	x	x	x	x	x	x			4-6n
wolfii	x	x	x	x					4n
Setaria verticillata	x	x	x	x	x		x	x	2n
Sorghum halapense	x	x		x	x	x	x	x	4-8n
vulgaris v. drummondii	x	x		x	x	x	x	x	4n
Spartina pectinata	x	x	x	x	x			x	4n
Stipa comata	x	x						x	4n
Uniola latifolia	x			x	x	x	x	x	2n
Zizania aquatica	x	x	x	x	x	x	x		2n
Hydrangea aborescens v. deamii				x	x		x	x	4n
sedum acre			x	x	x	x			4n
thelephioides			x	x	x	x			p.p.
Hypericum virginicum			x	x		x			4n
Scutellaria australis	x	x				x	x	x	4n
Teucrium canadense				x	x	x			2n
Cassia hebecarpa			x	x	x	x	x		2n
Comptonia peregrina		x	x	x	x	x	x		4n
Hibiscus lasiocarpos						x	x	x	p.p.
Forestiera acuminata			x					x	2n
Fraxinus tomentosa	x	x					x	x	2n
Styrax americana						x	x	x	2n
Cypripedium acaule			x	x	x	x	x		2n
Plantago pusilla		x	x	x				x	2n
Phlox amplifolia						x	x	x	2n
Phlox carolina v. triflora						x	x	x	2n

TABLE I—(Continued)

Indiana extraneous species and polyploidy

| Species | | General distribution outside Indiana Compass Directions | | | | | | | |
Species	W	NW	N	NE	E	SE	S	SW	Ploidy
ovata				x	x	x	x		2n
Clematis pitcheri	x	x						x	2n
Ranunculus bulbosus				x	x	x	x		2n
Thalictrum perelegans						x	x		p.p.
Fragaria vesca			x	x	x		x		2n
Geum laciniatum			x	x	x		x		6n
virginianum				x	x	x	x		6n
Prunus lanata						x	x	x	p.p.
Galium labradoricum			x	x	x				p.p.
Penstemon canescens				x	x	x	x		2n
deamii	x	x							2n
tubaeflorus	x	x						x	2n
Veronica glandifera				x	x				4n
Valerianella chenopodifolia			x	x	x	x			p.p.
Viola missouriensis	x	x					x	x	6n
triloba				x	x	x	x		6n
Vitis labrusca				x	x	x	x		2n

TABLE II

Polyploidy among di- and monocotyledons in Indiana extraneous species

| Family—Dicotyledonae | Genera | | Species | |
Family—Dicotyledonae	Polyploids	Diploids	Polyploids	Diploids
Asclepidaceae		1		1
Boraginaceae	1		3	2
Campanulaceae	1		1	
Caprifoliaceae	1	2	1	4
Caryophyllaceae	1		1	
Compositae	3	5	4	16
Cruciferae	2	1	2	2
Dipsacaceae		1		1
Ericaceae	1	1	1	1
Euphorbiaceae	1		1	
Grossulariaceae	2		3	
Hypericaceae	1		1	
Labiatae	1	1	1	1
Leguminosae		1		1
Malvaceae	1		1	
Myricaceae	1		1	

TABLE II—(Continued)

Polyploidy among di- and monocotyledons in Indiana extraneous species

Family—Dicotyledonae	Genera Polyploids	Diploids	Species Polyploids	Diploids
Oleaceae		3		3
Plantaginaceae		1		1
Polemoniaceae		1		3
Ranunculaceae	1	2	1	2
Rosaceae	2	1	3	1
Rubiaceae	1		1	
Scrophulariaceae	1	1	1	3
Valerianaceae	1		1	
Violaceae	1		2	
Vitaceae		1		1

Family—Monocotyledonae	Genera Polyploids	Diploids	Species Polyploids	Diploids
Amaryllidaceae	1	1	1	1
Cyperaceae	3	1	13	1
Gramineae	41	23	71	44
Orchidaceae		1		1
Totals and percentages:				
Dicotyledonae	24	23	30	42
	51%	49%	42%	58%
Monocotyledonae	45	26	85	47
	63%	37%	64%	36%

TABLE III

Summarized relations of polyploids and diploids

	Polyploids Number	Percentage	Diploids Number	Percentage
Dicot Species	30	42%	42	58%
Dicot Genera	24	51	23	49
Monocot Species	85	64	47	36
Monocot Genera	45	63	26	37
Total Species	115	56.5	89	43.5
Total Genera	69	58.5	49	41.5
Species on northern limits of range	40	50	40	50
Species on southern limits of range	59	69	26	31

DISCUSSION

According to Friesner (10) 45% of the species of fern and seed plants occurring in Indiana are on the borders of their present-day range and are therefore on critical ground. Their survival depends upon their ability to adapt themselves to a habitat which is more rigorous than the optimum since it represents the limit of distribution. (For this study, all plants which are on the limit of their range in Indiana are considered as extraneous species).

It has long been known that most plants show greater vigor if present in polyploid form. In most cases the tetraploid is the optimum ploidy and such plants are larger, stronger, and more viable than the diploids. In other cases octoploids are the optimum. At any rate, experimental evidence has shown that in cases where diploid species develop tetraploid races, the tetraploids are more often stronger and able to withstand more extreme habitat conditions (4). Often when diploid races from a mild climate are transplanted into a very cold or alpine environment they develop into polyploid types. Thus it has been found that an increase in rigor of habitat tends to increase ploidy.

Gustafsson (13) gives the credit to polyploids for survival following glaciation and climatic changes. He holds that the isolated communities which result from climatic change cross-breed and result in stuffing the species with lethals of different strength. These isolated communities, which have been cut down from original populations by the climate change, successively homozygotize, giving lethal recessives a chance to function. The strong heterozygotes disappear and the species is faced with degeneration. However, if a polyploid arises, the lethals immediately lose most of their fatal effect; inbreeding is thus not so dangerous, and the cross-breeding populations tend to become self-fertilizing to a high degree. The resulting polyploid populations now possess a double number of favorable genes (double if tetraploid, triple if hexaploid, etc.), but do not have the destructive effects of the lethals. These plants cover the area and initiate a new and vigorous community.

Gustafsson (13) holds that the polyploids are produced in such cases of change in climate in the following way: If a species continues to grow at a temperature below its optimum, its meiosis is subjected to repeated cold shocks which prevent reduction-division and result in the formation of unreduced gametes. The union of two such

gametes, of course, results in offspring containing exactly twice the chromosome complement of the parents . . . a tetraploid in the case of diploid parents. These will be continuously fed into the species and for this reason many diploids will automatically give rise to tetraploids, then hexaploids, then octoploids, if further unreduced gametes of polyploids are involved. When polyploids arise in this manner, it is not because of any inherent lack of viability in the diploids; it is simply a response to the colds. Such polyploids are invariably hardier than the original diploids. In cases where the species is adapted by special physiological properties to withstand the increased cold, the species remains diploid.

Several explanations for the increased vigor of polyploids have been advanced. The most logical, however, is propounded by Melchers (18) who says, "Better adaptability of polyploids as compared with diploids lies in the fact that genes for selection-worthy characters may be accumulated in a greater quantity than in diploids." This seems particularly true in cases of multiple factors in which the greater the number of genes present, the greater the effect, the genes being cumulative in effect. An example of this type of character is cold hardiness.

Among the genera represented, 58.5% are polyploid, while only 41.5% are diploid. Of the species studied, 56.5% are polyploid, while 43.5% are diploid. Of course, since there are about 800 extraneous species in Indiana (9) and only 172 were utilized for this study, it cannot be stated with complete certainly that the above percentages hold for the entire collection of extraneous species. However, since thirty families and 118 genera are included in the number studied, it seems that a fairly representative idea of the ploidy of these extraneous species in general can be obtained from the 172 used. Thus it would appear that over half of the species extraneous to Indiana are found in polyploid, usually the tetraploid, form.

The grasses, because of their commercial value, have been studied cytologically to a greater extent than have the other families. According to Cook (5), 62% of the Indiana grasses are extraneous; thus about 16% of the total extraneous species here studied are grasses.

Love and Love (16) found that the percentage of polyploid monocots increased with latitude and extremes of climate. Dicotyledonous plants, on the other hand, decrease as the climate becomes more severe. The predominance of polyploids among monocats seems to be the

rule. From table II it may be seen that of the dicot species studied, the diploids exceed the polyploids, (58% diploids to 42% polyploids). Among the monocots, however, only 36% are diploids and 64% polypoids. Heiser (14), in a study of California weeds, found that of the monocots, 65% were polyploids and 35% were diploids, while among the dicots no great difference in percentages of polyploids and diploids was evident. His percentages of ploidy for monocots among California weeds are almost identical with the results of the present tabulation of Indiana extraneous species of monocots (64% to 36%).

In table III it will be seen that only 50% of the extraneous species reaching northern limits in Indiana are polyploid, while 69% of those reaching southern limits are polyploid. Since species reaching northern limits in Indiana have a general southern distribution and those reaching southern limits have a northern distribution, it appears that these results agree with those of Love and Love (16).

An interesting fact borne out in this study is that the genera which show polyploidy in their species are among the most hardy and persistent, e.g., such genera as Hordeum, Sorghum, Thalictrum, Arabis, Prunus, Hypericum, Viola, Vaccinium, Veronica, Lonicera, Crepis, and Senecio. Burton (3) has pointed out that the most promising pasture species of Paspalum are tetraploid.

There are many exceptions to the general rule that polyploidy tends to develop where the habitat is more rigorous. Some of these exceptions are found among the Indiana extraneous species. Among them are such genera as Viburnum, Fragaria and Forestiera. Members of the genus Viburnum are found in Asia, Europe, and North America over a great variety of habitats, yet the plants are always diploid, (6). *Fragaria vesca* shows the same characteristic, being found in Indiana and in Ecuador as a diploid (6). *Forestiera acuminata,* ranging from southwestern Indiana to Texas and South America, is diploid throughout its range, (6). The genus Poa, on the other hand, is world-wide in range with chromosome numbers varying from 14 to 106 and its ploidy from diploid to 15-ploid, (15). *Leavenworthia uniflora* is a hexaploid and is found the farthest north of any of the species of the genus, (1). As Gustafsson has pointed out, it is self-fertile and quickly invades and covers a new area.

Whatever the complete casual relations for the development of polyploids are, it is apparent that the percentage of polyploids increase as conditions for growth became more widely divergent from the op-

timum for that particular species. The presence of a high percentage of polploidy among the plants which are extraneous and which are therefore near the limit of their distribution range is in line with this observation. We must not make the error, however, of assuming that polyploids always develop where the climate is extreme or environment is unfavorable. Clausen, Keck and Hiesey (4) stress gene balance as determining adaptability to environment. They point out that not only change in chromosome number must be recognized in polyploids, but also change in numbers of genes. If large numbers of favorable genes are present, the polyploid form is more vigorous; however, if the increase in chromosome number results in the multiplication of large numbers of unfavorable genes, the polyploid form is less adaptable.

We cannot claim that polyploids develop as means of adaptation to more rigorous habitats among floras as a whole. The figures obtained from this study clearly indicate that only among the monocots is such a relationship shown. There is no such correlation between polyploidy and dicot species as a whole. Of course, there are many instances among individual dicots where the increased adaptability of the polyploid over the diploid is strikingly illustrated, (4).

SUMMARY AND CONCLUSIONS

1. Among 172 species extraneous to Indiana, 56.5% are polyploid, while 43.5% are diploid. Among 118 genera, 58.5% have polyploid species.

2. Of the dicot extraneous species studied, 58% are diploids and 42% polyploids. Among the monocots, 36% are diploids and 64% polyploids.

3. Of the extraneous species reaching their northern limit in Indiana, 50% are polyploid; of those reaching their southern limits, 69% are polyploid.

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COASTAL PLAIN FLORA IN INDIANA BOTANICAL AREAS

By VIRGINIA LAMERSON

Harper (8), Peattie (11), and McLaughlin (10) have dealt with plants of the Atlantic Coastal Plain which occur in inland extensions about the Great Lakes. Harper (8) observed that many plants of the coastal plain which occur in New England extend not only southward along the Atlantic Coast but are also found extending westward as far as Minnesota. Peattie listed 90 species occurring in the Great Lakes region alone and McLaughlin found that many of these species extend west to the sand barrens of northwestern Wisconsin.

For the state of Indiana, it has long been known that the flora of the sand dunes bordering the shore of Lake Michigan is remarkable for the type of vegetation found there. Many of these species are of coastal plain derivation and their presence has been explained by various authorities. Friesner (6) states that extraneous eastern species which occur in Indiana fall into two groups, viz., those characteristic of the Appalachian plateau, and those characteristic of the Atlantic Coastal Plain as a whole. The present paper deals with the Coastal Plain species found in the various Indiana botanical areas.

The plant communities, which are recognized as distinctively coastal plain communities, reach their best development in the lower area which is near the ocean. Some species found on the Coastal Plain are limited exclusively to that area and do not occur inland. Others extend northward and westward and occur throughout temperate North America. Another group which may occur generally along the Coastal Plain extends inland only locally. Coastal Plain plants, therefore, may be defined from several standpoints. Peattie defines the Coastal Plain flora as those species occurring in areas of acid bogs, sand barrens, savannahs, and marshes anywhere from the Gulf of Mexico and Florida to Cape Cod, Nova Scotia and Newfoundland. He excludes the flora of salt marshes, estuaries, the Piedmont country and those plants which have too general a range aside from the Coastal Plain.

The present paper includes those Coastal Plain plants which occur

generally on the Coastal Plain itself and which extend inland with a limited range only. Those with too general a range and those extending over temperate North America have been excluded even though they may occur throughout the Coastal Plain area.

METHODS

Species accepted by Braun (7), Fernald (2, 3, 4, 5), Hanes (7), Harper (8, 9), Peattie (11), Svenson (12) and Wells (13) as belonging to the coastal plain were used for consideration. Distribution of all species was then tabulated as to occurrence in Indiana botanical areas. Indiana, as a whole, was divided into five natural areas, i.e., the Lakes area, Ohio and Wabash River Counties, the Illinoian Drift Plain, the Tipton Till Plain, and the Unglaciated area. Species found in any of the specified areas were tabulated under that particular heading.

OBSERVATIONS

Table I lists 207 species, varieties and forms of coastal plain species occurring in Indiana, together with the botanical areas in which they are found in Indiana. It will be noted from table I that 85.5% of the Coastal Plains species occur in the Lakes area, 42% in the Ohio River and Wabash River Counties, 34.3% in the Tipton Till plain, and 28.3% each in the Illinois Drift plain and the Unglaciated area.

The Lakes area also contains the largest number of entities limited to any single area. Eighty-nine entities, or 43% of the total number of coastal plains entities are limited to this area. Twelve entities, or 5.8% of the total, are limited to the Ohio River and lower Wabash River counties.

MIGRATION OF COASTAL PLAIN PLANTS

There have been several theories advanced as to the occurrence of coastal plain plants inland, especially those around the Great Lakes which are disjunct. A survey of coastal plain plants shows the greater majority of them to be confined in the interior to ecologically similar habitats.

Svenson (12) and Peattie (11) point out that eastern plants have very probably reached Indiana through the Mohawk Valley, by the St. Lawrence Valley, and from regions adjacent to the Glaciated area.

McLaughlin contends that there were three paths of post-glacial migration: (1) the Hudson-Mohawk-Finger Lakes, (2) the Hudson-Ottawa-French River, and (3) the Mississippi River. He points out that Peattie concluded that very few coastal plain plants in the Great Lakes region reached Indiana by way of the Mississippi River. Data in table I reveal that the Lakes area has more than twice as many coastal plains species as any other area and that the counties bordering on the Ohio and Wabash River are second in percentage of total species. A great part of Indiana is drained through the Wabash and Kankakee Rivers into the Mississippi River. The region about the Great Lakes, therefore, could have received its species from at least three possible sources: the Mississippi Valley, the Mohawk-Hudson outlet, and the Ottawa connective. The data support the view that the greater percentage of coastal plains species occurring in the Lakes area originally arrived there by northern routes of migration rather than by the Mississippi Valley route. The fact that the Ohio River and lower Wabash River counties contain 42% of the coastal plains species indicates that the southern or Mississippi valley route of migration was also of considerable significance. Both hydrophytic plants and plants demanding sandy soil, such as those found along the Atlantic Coastal Plain, find a higher proportion of the habitats hospitable in the Lakes area than in any other area of the state. The Unglaciated area is poor in habitats for coastal plains species because of the hilly terrain, the residual soil, the insufficient moisture and the lack of mineral salts present. There are few habitats found in the Unglaciated region or the Illinoian Drift plain which are characteristic of the Lakes area. The drainage in the eastern lobe is very poor because of the level ground. This, together with the clayey soil and poor aeration is not so conducive to the development of coastal plain species as on the western lobe which has better drainage due to the underlying gravel layers.

SUMMARY

1. This paper presents a distributional study of 207 species of Atlantic Coastal Plain plants which extend inland with a limited distribution only. It excludes those which have a general distribution throughout the United States.

2. Of the total number, 177 or 85.5% are found in the Lakes area.

3. Eighty-seven or 42% of the total entities are found in the Ohio River and lower Wabash River counties.

4. The Wisconsin Drift or Tipton Till plain contains 71 or 34.3% of the total coastal plain species occurring in Indiana.

5. The Illinoian Drift plain and the Unglaciated area each have 60 entities or 28.3% of the total.

6. The Lakes area is the only area having an appreciable number of the species which are limited in Indiana to any one area. Eighty-nine species, or 43% of the total, are limited to the Lakes area.

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TABLE I

Species	Dunes and Lakes Area	Ohio and Wabash R. Co.	Tipton Till Plain	Illinois Drift Plain	Un-glaciated Area
Alnus serrulata v. vulgaris	x	x	-	x	x
Ammophila breviligulata	x				
Andropogon elliottii		x		x	x
A. scoparius	x	x	x	x	x
Aristida tuberculosa	x				
Arundinaria gigantea		x			x
Aureolaria pedicularia v. ambigens	x				
A. pedicularia v. intercedens	x				
A. pedicularia v. typica	x				
A. virginica	x	x	x		
Bartonia virginica	x		x	x	x
Betula nigra	x	x	x	x	x
Bidens discoidea	x	x	x	x	
Buchnera americana	x				
Cakile edentula v. lacustris	x				
Calopogon pulchellus	x	x	x		
Carex alata	x				
C. albolutescens		x		x	x
C. annectens	x	x			x
C. buxbaumii	x				
C. emmonsii	x				
C. gigantea		x			
C. howei	x				
C. longii	x				
C. louisianica		x			
C. richii	x	x	x		x
Carex seorsa	x				
C. sterilis	x		x	x	
C. stricta	x		x		
C. tonsa	x				
Castilleja coccinea	x	x		x	
Chelone glabra v. typica	x		x	x	x
Cladium mariscoides	x		x		
Commelina communis	x	x	x	x	x
C. erecta v. deamiana	x	x		x	
Convolvulus sepium v. pubescens	x				
Cyperus engelmanni	x		x		
Decodon verticillatus	x	x	x	x	x
D. verticillatus v. laevigatus	x		x		x
Drosera intermedia	x		x		
Dulichium arundinaceum	x	x	x	x	x
Echinochloa walteri	x				
E. walteri f. laevigata	x	x			

TABLE I—(Continued)

Species	Dunes and Lakes Area	Ohio and Wabash R. Co.	Tipton Till Plain	Illinois Drift Plain	Un- glaciated Area
Eleocharis equisetoides	x				
E. geniculata	x				
E. melanocarpa	x				
E. microcarpa v. filiculmis	x				
E. olivacea	x				
E. pauciflora v. fernaldii	x				
E. quadrangulata v. crassior	x	x			x
E. robbinsii	x				
E. rostellata	x		x		
Eriocaulon septangulare	x				
Euphorbia polygonifolia	x				
Fimbristylis autumnalis v. mucronulata	x	x	x	x	x
F. caroliniana	x				
Fuirena squarrosa	x				
Galactia volubilis v. mississippiensis		x		x	
Galium tinctorium	x	x	x	x	x
Gerardia paupercula v. typica	x		x		
G. purpurea	x	x	x	x	
Gratiola neglecta	x	x	x	x	x
G. virginiana	x	x	x		x
Gymnopogon ambiguus				x	
Habenaria ciliaris	x	x			
H. flava	x				
Helianthus giganteus	x	x	x		x
Hemicarpha drummondii	x				
H. micrantha	x		x	x	
Hibiscus moscheutos		x	x	x	x
H. palustris	x				
Hieracium canadense v. fasciculatum	x				
H. gronovii	x	x	x	x	x
Hottonia inflata		x			
Hudsonia tomentosa v. intermedia	x				
Hydrocotyle umbellata	x				
Hypericum adpressum	x	x			
H. kalmianum	x				
H. majus	x				
Ilex decidua		x		x	
Iris virginica v. shrevei	x	x	x	x	x
Isoetes engelmanni		x			
Juncus articulatus	x				
J. balticus v. littoralis	x				
J. biflorus	x	x		x	x
J. effusus v. pylaei	x				

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TABLE I—(Continued)

Species	Dunes and Lakes Area	Ohio and Wabash R. Co.	Tipton Till Plain	Illinois Drift Plain	Un-glaciated Area
J. effusus v. solutus	x	x	x	x	x
J. gerardi			x		
J. greenei	x	.			
J. marginatus	x	x			x
J. pelocarpus	x				
J. scirpoides	x				
Jussiaea decurrens		x			
Lechea leggettii v. moniliformis	x				
L. minor	x			x	
Leucospora multifida	x	x	x	x	x
Linaria canadensis	x				
Lindernia anagallidea	x	x		x	x
L. dubia v. riparia	x	x	x	x	x
L. dubia v. typica	x	x	x	x	x
Linum striatum	x			x	x
Lithospermum croceum	x	x			
Ludwigia glandulosa v. typica		x			
L. sphaerocarpa v. deamii	x				
Lupinus perennis	x				
Lycopodium inundatum	x				
Lycopus americanus v. longii	x		x	.	x
L. sessilifolius	x				
Melampyrum lineare v. latifolium	x				
M. lineare v. pectinatum	x				
Mikania scandens	x				
Mimulus alatus		x	x	x	x
M. ringens	x	x	x	x	x
Monarda punctata v. villicaulis	x	.	x		
Myriophyllum heterophyllum	x				
M. scabratum	x				
Najas gracillima					x
Nelumbo lutea	x	x		x	x
Nuphar advena	x	x	x		x
Panicum addisonii	x				
P. albemarlense	x		x		
P. auburne	x				
P. deamii	x				
P. lindheimeri	x	x	x	x	x
P. lucidum	x				
P. mattamusketense					x
P. meridionale	x				
P. oligosanthes	x	x		x	
P. spretum	x				

TABLE I—(Continued)

Species	Dunes and Lakes Area	Ohio and Wabash R. Co.	Tipton Till Plain	Illinois Drift Plain	Un-glaciated Area
P. verrucosum	x				
Pedicularis canadensis	x	x	x	x	x
Peltandra virginica	x	x		x	x
Penstemon alluviorum		x		x	x
Phlox pilosa v. amplexicaulis		x			
Pogonia ophioglossoides	x				
Polygala cruciata	x				
Polygonella articulata	x				
Polygonum exsertum	x		x	x	
P. pennsylvanicum v. genuinum	x	x	x	x	x
P. pennsylvanicum v. laevigatum	x	x	x	x	x
Pontederia cordata	x	x	x		
P. cordata f. angustifolia	x	x	x		
P. cordata f. latifolia	x	x	x		
Populus heterophylla	x	x	x	x	
Potamogeton crispus	x		x		
P. hybridus	x	x	x	x	x
P. pulcher	x	x			
Psilocarya nitens	x				
P. scirpoides	x				
Psoralea psoralioides v. eglandulosa	x	x		x	x
Ptelea trifoliata	x	x	x	x	x
P. trifoliata v. deamiana	x		x		
Quercus falcata		x		x	x
Q. prinoides	x				
Ranunculus oblongifolius		x			
R. pusillus		x			
Rhexia virginica	x	x	x	x	
Rhynchospora globularis v. recognita	x				
R. capitellata	x				
R. macrostachya	x				
Ribes americanum	x	x	x		
Rotala ramosior v. typica	x				
Sagittaria graminea	x	x	x		x
Salix gracilis v. textoris	x		x		
Salsola pestifer	x		x		
Scirpus acutus	x		x		
S. purshianus	x				
Scirpus rubricosus	x	x			x
S. smithii	x				
S. smithii v. setosus	x				
S. subterminalis	x				
Scleria reticularis	x				

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TABLE I—(Continued)

Species	Dunes and Lakes Area	Ohio and Wabash R. Co.	Tipton Till Plain	Illinois Drift Plain	Un-glaciated Area
S. verticillata	x		x		
Scrophularia marilandica	x	x	x	x	x
Sisyrinchium atlanticum	x	x		x	
S. graminoides	x	x	x	x	x
Smilax rotundifolia	x	x	x	x	x
Spigelia marilandica		x			
Stachys hyssopifolia	x				
Stipa avenacea	x				
Stylosanthes biflora		x		x	x
Styrax americana	x	x			x
Taxodium distichum		x			
Trachelospermum difforme		x			
Triglochin maritima	x				
Trillium cernuum v. macranthum	x				
Triplasis purpurea	x				
Typha angustifolia	x		x	x	
Utricularia cornuta	x				
U. gibba	x	x	x		x
U. purpurea	x				
U. resupinata	x				
Vaccinium arboreum		x			x
V. corymbosum	x				
V. oxycoccus	x				
Veronica peregrina v. typica	x	x	x	x	x
V. peregrina v. xalapensis	x	x	x	x	
Viburnum pubescens v. deamii		x	x	x	x
Viola lanceolata	x	x	x	x	
V. primulifolia	x				
Vitis vulpina	x	x	x	x	x
Woodwardia virginica	x				
Xyris caroliniana	x				
X. torta	x				
Zizania aquatica	x				
Z. aquatica v. angustifolia	x				
Z. aquatica v. interior	x				
Total all areas 207					
Total species per area	177	87	71	60	60
% of total species in each area	85 5	42	34.3	28.3	28.3
Species limited to each area	89	12	1	0	0
% of species limited to each area	43	5.8	0.5	0	0

A COMPARISON OF TOTAL BACTERIA COUNTS OF RAW AND PASTEURIZED MILK

By Donald H. Holmes

The purpose of this study was to compare the total bacteria count in samples of raw and pasteurized milk from the Golden Guernsey Association, of Indianapolis, Ind., using both the Breed-Prescott direct microscopic method and the standard agar plate method. In addition, a record of the types of organisms observed in the direct microscopic count was made for each sample.

Producers, desirous of checking their raw milk supply, usually ask for either plate or direct counts but seldom request both counts on the same sample. Results of counts from the two methods often appear quite confusing and contradictory so that the producer is unable to decide which count to accept as correct. However, numerous research workers have made such comparison counts (5) and their results show direct count to plate count ratios varying from 44:1 to 4:1. The latter ratio is commonly accepted in dairy analysis work as a "normal" ratio. It is by no means a hard and fast one as will be observed later in this paper. Individual counts can show wide deviations from this ratio. Some reasons for the differences in counts are: (1) Factors affecting the plate count: (a) failure of all organisms to grow in media used; (b) failure of all organisms to grow at incubation temperatures used; (c) single colonies developing from clumps of organisms; (d) sampling and technique errors. (2) Factors raising or lowering direct count: (a) failure of all organisms to stain, or staining of dead organisms; (b) sampling and other technique errors. Both plate and direct methods of milk examination are subject to numerous errors in addition to those given above.

MATERIALS AND METHODS

The large supply of raw milk samples necessary was readily obtainable at the Moseley Laboratory in Indianapolis. The samples chosen were all from Guernsey cows and were produced on farms belonging to the Golden Guernsey Association. This milk has always shown a consistently low raw and correspondingly lower pasteurized count.

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A raw sample, when received at the laboratory, was first smeared on a standard slide using a platinum wire loop to apply the milk and resulting in a smear of one square centimeter area. The sample was then split into two parts, one portion to be pasteurized at 143-144° F. for 30 minutes, then cooled and plated at a dilution of 1/100 and also smeared again on a different slide using the same procedure as the first smear. The other portion was plated raw immediately at dilutions of 1/100 and 1/10,000. The pasteurized sample was then placed in a cooler for approximately four hours, after which it was again smeared on a third slide. All three slides were then stained with methylene blue solution and read, using the oil immersion lens. The plated samples were allowed to cool before inverting and placing them in the incubator at 37° C. for 48 hours. At the end of the incubation period they were counted on a Quebec counter.

As each smear was counted, a record was kept of the types of organisms observed. The organisms (see table 1) were separated into individual cocci, individual rods, diplococci, rods in clumps, streptobacilli, streptococci, and staphylococci. One hundred fields were read per smear and the figure obtained multiplied by 3000 to get the total organisms present per milliliter of milk. This counting procedure was followed on all smears except a few showing very high counts on the first few fields examined. In such cases 30 fields were counted and the total multiplied by 10,000.

Each plate was counted after the incubation period and the total number of colonies found was multiplied by the dilution factor. In the case of the raw counts, when two plates were made, one at 1/000 and one at 1/10,000, only the plate having between 30 and 300 colonies was counted and this figure multiplied by the dilution factor used. In case both plates had between 30 and 300 colonies, the average was computed and accepted as the proper total count for the sample.

OBSERVATIONS

The milk used in this study is one of the cleanest milks in use today. It is produced and handled with special care in order to keep the bacteria count low and the product clean. For this reason these samples all show quite low counts, some of the raw samples even being completely free of organisms on the Prescott-Breed smears. However, these same raw samples, when plated, showed counts from 400 to 23,000. On the smears of raw milk, staphylococci were most

abundant, then streptococci, individual cocci, rods in clumps, streptobacilli, individual rods, and diplococci, in decreasing abundance. The staphylococci also survived pasteurization better than any other organism, followed by individual cocci, streptococci, individual rods, rods in clumps, diplococci and streptobacilli. The third smear, made four hours later from the same pasteurized sample of milk, showed staphylococci predominant, streptococci next, closely followed by individual cocci, individual rods, then rods in clumps, diplococci and streptobacilli (table I).

Using the total counts (see table I) found on these samples by the plate and direct methods, the following ratios were obtained:

$$\frac{\text{Raw direct count}}{\text{Raw plate count}} = \frac{3.05}{1}$$

$$\frac{\text{Pasteurized direct count}}{\text{Pasteurized plate count}} = \frac{6.21}{1}$$

$$\frac{\text{Raw plate count}}{\text{Pasteurized plate count}} = \frac{13.38}{1}$$

$$\frac{\text{Raw direct count}}{\text{Pasteurized, smeared 4 hours later}} = \frac{6.90}{1}$$

$$\frac{\text{Raw direct count}}{\text{Pasteurized direct count}} = \frac{6.56}{1}$$

$$\frac{\text{Pasteurized direct count}}{\text{Pasteurized, smeared 4 hours later}} = \frac{1.05}{1}$$

Staphylococci were found most often on all three smears: raw, pasteurized, and the pasteurized-smeared-four-hours-later. Their presence is often an indicator of utensil contamination, (3). Streptococci were present in greater numbers than all other organisms except staphylococci on raw smears and the smears made four hours after pasteurization, but were third on the smears made immediately after pasteurization. Individual cocci were second on the pasteurized smears and third on the other two. These organisms are associated with utensil contamination and poor cooling. No particular significance can be attached to the other organisms present in these smears. The counts were low under all conditions.

The ratio of raw-direct to raw-plate count was 3.05:1. This is much better than the 4:1 ratio considered "normal" in the industry. In this study all ratios were obtained by using the pertinent averages of all counts on the total of 142 samples used. The ratio of pasteurized-direct to pasteurized-plate count was 6.21:1. This ratio is considerably different from the raw ratio and was probably influenced by the staining of dead cells in the pasteurized-direct smears.

The ratio of raw-plate to pasteurized-plate count was 13.38:1. This ratio is much higher than the pasteurized-direct to pasteurized-plate since only living cells in the pasteurized milk were to be compared with those of the raw milk. The ratio of raw-direct to pasteurized-direct count was 6.56:1 and raw-direct to pasteurized-smeared-four-hours-later was 6.90:1.

Finally, the ratio between the pasteurized-direct count and the pasteurized-smeared-four-hours-later count was 1.05:1. This ratio is insignificant, but to the extent that it may have significance, it indicates that some of the organisms stained in the smears prepared immediately following pasteurization were not stained in the smears prepared four hours after pasteurization. Immediately after pasteurization these organisms, although dead, possess the ability of taking a staining preparation, but after a period of time, approximately four hours in this case, they were no longer stainable and cansequently failed to appear on the smear, (1, 2).

CONCLUSIONS

1. In raw Golden Guernsey milk, the most common organisms found are of the staphylococcus group, many of which survive pasteurization and are the organisms most commonly found in the pasteurized samples.

2. The "normal" 4:1 direct microscopic count to plate count ratio is seldom attained. The raw ratio in this case being 3.05:1 and the pasteurized ratio 6.21:1.

3. When a milk sample is smeared and stained immediately after pasteurization, numerous dead bacteria as well as bacteria which have survived pasteurization are stained and counted. When the pasteurized sample is allowed to stand for a period of time (four hours in this case) some of the bacteria which stained before fail to stain.

4. The ratio of pasteurized and smeared-immediately to pasteurized and smeared-four-hours-later was 1.05:1. This ratio would probably have been higher and more significance could have been attached to it if the original raw milk samples had shown higher counts.

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TABLE I

Treatment	Individual		Diplococci	Rods in Clumps	Streptobacilli	Staphylococci	Streptococci	Total per ml.	Av. 142 Samples Plate Count
	Cocci	Rods			Direct Counts—Averages of 142 samples				
Raw	13.5	4.13	1.15	9.85	3.72	97.88	33.92	528,206	173,300
Pasteurized	4.0	1.74	0.47	0.52	0.25	16.76	3.11	80,472	12,954
Smeared 4 hours after pasteurization	3.10	1.33	0.49	0.54	0.28	16.35	3.62	76,500	—

THE EFFECT OF ANTHOCYANIN FILTERS ON PLANT BEHAVIOR AND DEVELOPMENT[1]

By HOWARD E. MANNING

The red color of leaves found in nature during various seasons has long intrigued scientists and laymen alike. The voluminous literature is also evidence of the interest the phenomenon has aroused. Onslow's (12) 'Anthocyanin Pigments of Plants' and 'The Biological Effects of Radiation,' edited by Dugger (3) are the two most exhaustive books on the chemical and physical aspects of anthocyanin. Lippmma (8) came to the conclusion that anthocyanin plays a role of protection and that it is a genetically controlled characteristic of plants. It is thought by some that the pigments aid in temperature rise and thus cause increased transpiration. Chemically, the anthocyanin pigments occur in a number of forms. The most common two are found in beets and grapes.

Nicolas (11) found that red leaves exhibited increased respiration over green leaves. Charlton (2), Popp and Brown (13, 14) and Teodoresco (15) found that red light caused elongated cells with resulting longer petioles and internodes. Gort's work (4) showed that a 10 day exposure, after germination, to red light followed by natural light, stimulated vegetative and reproductive development.

Johnston (7) reported that red light inhibits root growth and that photosynthesis has a maximum in red light and a lower maximum in the blue. Hoover's (5) work with wheat also shows this condition in photosynthesis with the maximum at 655 millimicrons in the red and at 400 in the blue. The thickness and surface area of leaves is reduced by red light, according to Teodoresco (15). Arthur (1) reported that anthocyanins had absorption bands at 2670, 3310, 4000, 4540, 5040, and 5700 Å.

Meier (9), working with the unicellular alga, Stichococcus bacillaris, recorded less cell multiplication in a two weeks exposure to red light (600-750 $\mu\mu$) than in blue (400-520 $\mu\mu$) or daylight.

The present problem was undertaken to determine whether isolated anthocyanin red used as a light filter has effects on plant behavior and development similar to light filtered through red glass. No recorded experiments of this kind are known to the writer.

METHODS

The garden bean was used to observe light effects on root, stem, leaf and reproductive structure. The study was carried out in the laboratory greenhouse of Butler University. All plantings were made in individual pots of soil. The beans were kept in an incubator for 72 hours and were then transferred to the observation box in the greenhouse where four compartments permitted installation of light filters.

The observation box was built of plywood 76 cm. high with end pieces 76 cm. wide and the back and front 152 cm. long. Partitions were the same dimension as the ends of the box. These divided the box into the five compartments, 76 cm. from front to back, and 30 cm. wide, each with a glass top. This made possible the control of the quality of light admitted to the plants below. Top light only was used. The ends and partition pieces were fastened securely to the back with one-inch corner irons. The front was made removable for inspection and watering. It was fastened to the ends and partitions with corner irons and bolts like the other parts of the box, but wing-nuts here facilitated removal of the front.

Of the five compartments, four were covered by two pieces of window glass, Libby and Owens, grade B, double strength. The fifth was covered with one piece of the same glass and a piece of rub-flash red glass. The top piece of glass on one section was made into a shallow tray by sealing strips of wood 2 cm. square to the edges. Sealing was accomplished with heavy pitch. This tray was kept filled with a solution of beet juice in water to function as a filter. This made three compartments of clear glass, one clear glass with beet juice filter above (antho-red), and one of red glass supported by clear glass.

The antho-red solution was prepared by grinding two fresh beets through a food chopper. The grindings were extracted in 250 cc of tap water for five minutes. The resulting solution was filtered through fine cloth and made up to a volume of 400 cc by the addition of more tap water. The solution was changed every 24 to 72 hours according to the intensity and duration of sunlight. No artificial il-

lumination was used at any time. The clay pots containing the bean plants were imbedded in garden soil to reduce evaporation.

Potted bean seedlings were placed in two rows of nine each in the center of each compartment. They were watered daily and after 30 days all plants were removed. Roots, stems and leaves were measured and then dried in an oven at 100° C. before recording weights. A second lot of seedlings was treated in the same manner except that they were kept in the compartment for 55 days. When removed, the plants under red and antho-red filters were so retarded and dwarfed that measurements for comparisons with the control were unnecessary.

A third lot of seedlings was prepared, using 8 cm. pots. Twenty were selected for uniformity of size and vigor. Ten were placed in two rows of five each under antho-red light and ten were placed in a natural light compartment. At the end of 7 days, five pots were taken from each compartment and equally spaced in an area of 76 cm x 40 cm on a bench in an adjacent room of the greenhouse. At the end of 7 more days, the plants yet remaining in the observation box were removed and treated like the first ten on the same greenhouse bench.

The greenhouse bench was covered with sand and soil to a depth of 10 cm in which all pots were sunk. The plants were watered carefully and equally throughout the course of the experiment. When some of the plants were about 25 cm tall, all were supported in an upright position with the aid of string over head. This prevented light competition. The experiment was culminated June 27, 1949, and the procedure of the first planting was used for measurements and weights.

OBSERVATIONS AND RESULTS

All the experiments were carried on from late autumn until early summer. While the quality of sunlight varies considerably within that time, especially in the quantity of ultra-violet present, the glass of the greenhouse and of the observation box, being opaque to ultra-violet, eliminated it as a factor.

The results from red glass and antho-red filters are not identical (table I) but their effects on morphology (table I, fig. 1) were considered sufficiently similar to justify using antho-red only in the third planting (table II).

Fig.1.

Under Natural Light.

Under Natural Light.

Under Antho-Red.

Under Red Glass.

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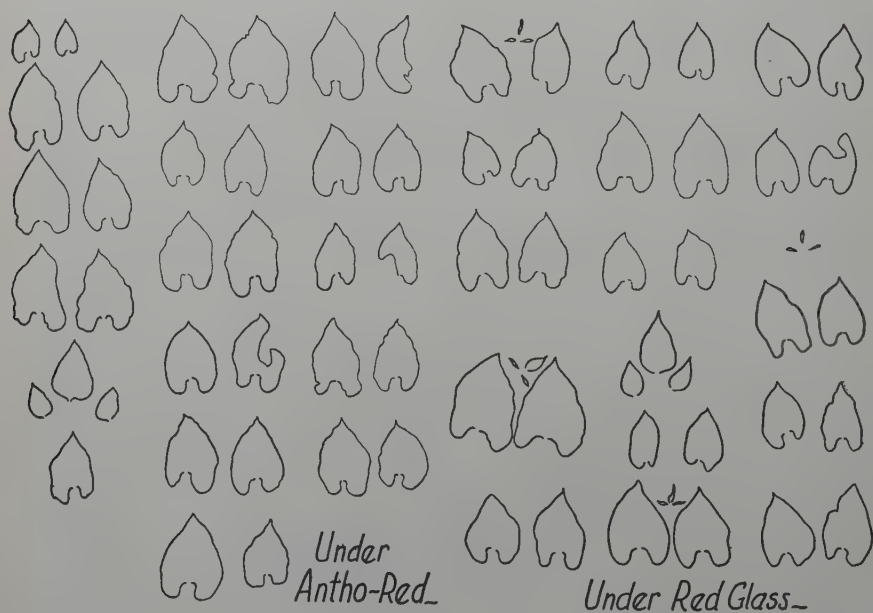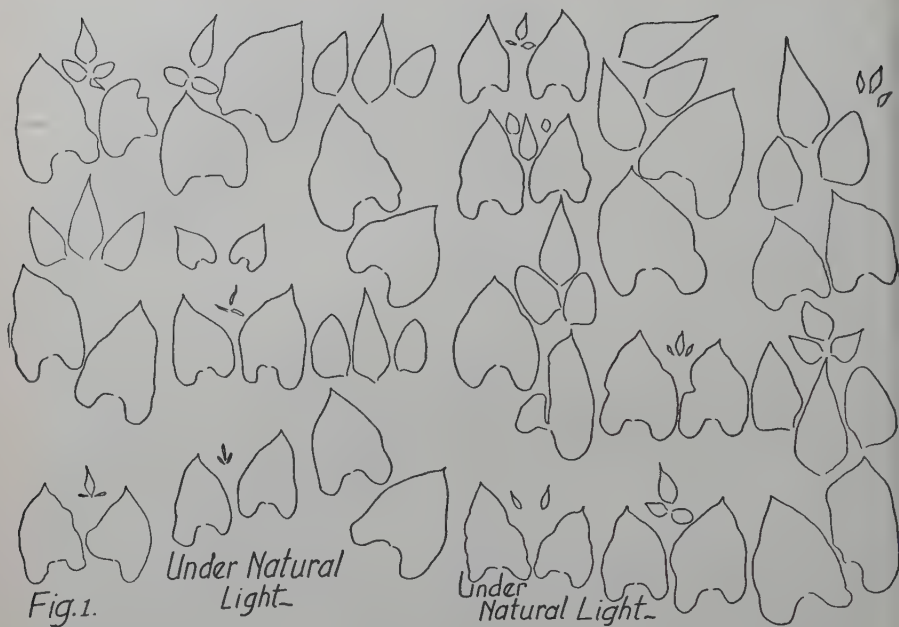
No measurements were made on the plants in the third planting until they were mature. At 7 days no differences were observed between plants under antho-red and natural light, but plants which grew under red glass or antho-red for 21 days or more were dwarfed, with fewer and smaller leaves than the controls. Also, their leaves were more rugose and almost hispid, with more stiff, short hairs. The areas between veins were bullate on the upper surface and cancellate on the lower surface. Apparently the veins had not grown as rapidly as the mesophyll and the margins. The margins were entire but the leaf edge was ruffled. The sinuses were narrow and the lobes more pronounced and turned in toward the petioles. In short, the leaves grown under antho-red and red glass were strikingly different from those under white light.

If we compare results of the first and third planting (tables I and II), it appears evident that length of first node is greater in plants grown under red light. It is most pronounced in those which had 14 days' initial growth under antho-red followed by white. This difference is not apparent in higher nodes. Total stem length is greater in plants grown under natural light for 30 days as compared with those grown under red light for the same time. However, plants initially grown (both for 7 and 14 days) under red light and then transferred to white light, had longer stems than comparable plants grown under white light. In this respect 14 days initial growth under red light is more beneficial than 7 days. The same comparisons apply to weights of stems (table II).

For all other structures except roots, the 7 days antho-red plants were superior. Entire stems were longer and heavier, number of leaves and area was greater, and pods weighed more. All plants grew tall more rapidly in the compartments with top light only than if no light restriction had been imposed.

DISCUSSION

As with so many functions in plants, the role played by anthocyanin is still poorly understood, and this warrants continued study of this phase of plant life. Most of the workers on this problem have used red glass filters and in order to determine whether anthocyanin may present a difference in the filtration of light from that of glass filters, the anthocyanin filter was devised and used simultaneously with an artificial filter of red glass. Some of the results obtained cor-

related remarkably well with the results of other workers (2, 14, 15). Thus, reduced development of root systems, involving both length and weight, had been reported by Johnston (7) as an effect of red glass filters. Similar, if not identical results were also obtained with antho-red filters in the present study (tables I, II).

The question may well be asked as to what relationship exists between expanse of leaf surface and photosynthetic efficiency. If an inverse relationship exists (as greater size of shade leaves indicates) then it may be inferred from the present results that a red filter has a double function, causing reduction in leaf size and compensating reduced photosynthetic surface with greater activity in the process itself (tables I and II). In the present study, leaves developed under red filters were one-third smaller in area than leaves grown in white light (fig. 1), yet they permitted development of plants of greater total weight than those grown in white light.

We may probably assume that accelerated photosynthesis may at least partly account for the stimulation of the beans received from the 7, 14 and 30 days of exposure to antho-red light. However, one must reserve definite conclusions to the time when effect of light on growth processes has been observed specifically. That red light has modifying influence on cell structure was shown by Charlton (2). She found that red light induced elongation of the cells and this in turn may explain the longer stems in beans grown under antho-red (tables I and II). In view of the striking morphological changes shown in tables I and II and figure 1, it seems clear, also, that the effect of red light is not limited to photosynthesis, but involves growth processes as well (tables I and II, fig. 1).

According to Arthur (1), anthocyanin has absorption bands at 2670, 3310, 4000, 4540, 5040, and 5700 Å (ultra-violet, violet, blue, and most of the green). From this it may be seen that in plants where anthocyanin-red occurs in the leaves, the chloroplasts are shielded from most of the green, blue, violet, and ultra-violet light waves. This brings about great changes in the normal light-plant relationship.

Most plants are green because the green of the spectrum is reflected from the chloroplasts. This means that the red, yellow and blue are being absorbed. Whatever the effect of white light may be, it may be concluded from the present results and those of others (5, 7) that photosynthesis is aided by red light, at least for a limited time.

SUMMARY

1. Experiments were conducted with filters made of anthocyanin from beets (antho-red) to determine the effect on growing beans.

2. Red light from a filter of anthocyanin extracted from beets and red light from a filter of red glass produce similar effects on plant behavior and development.

3. Beans exposed to red light for 30 days were stimulated in photosynthetic activity to produce heavier plants than the control although the leaf surface was reduced 1/3 in area.

4. Red light (both antho-red and red glass filters) induced most striking modifications in leaf size and leaf structure as compared with plants which developed in white light.

5. A 7-day exposure to red light after sprouting, followed by growth in white light, was best for development of stem diameter, stem length, number and area of leaves, weight of pods, and total weight of plants.

6. Exposure to red light for 55 days appeared to be lethal to beans.

7. All exposures to red light (7, 14, 30 days) reduced root development both as to length and as to weight.

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TABLE I

Quantitative results (averaged) on various morphological features of bean plants grown under red glass, antho-red filter and under clear glass

First Planting

Feature compared	30 Days Antho-red	30 Days Red Glass	30 Days Clear Glass Filter
Root length	22.5 cm	14.75 cm	23.35 cm
Root dry weight	.0720 gm	.0518 gm	.1060 gm
Length to 1st node	15.725 cm	18.60 cm	14.375 cm
Length 1st to 2nd node	8.20 cm	10.25 cm	8.575 cm
Entire stem length	29.92 cm	33.12 cm	35.65 cm
Dry weight of stem	.1242 gm	.1282 gm	.1301 gm
Stem diameter middle 1st internode	3.7 mm	3.9 mm	3.4 mm
Leaves per plant	2.00	1.83	3.61
Leaf area per plant	2.035 sq. in.	1.877 sq. in.	6.20 sq. in.
Dry weight of leaves	.0382 gm	.0308 gm	.0719 gm
Weight total parts	.2345 gm	.2109 gm	.2682 gm

Second Planting

55 Days Growth

Antho-red and red glass	Clear glass filter
All plants about 30 cm tall.	All plants about 45 cm tall and erect.
Leaves small, curled rugose.	Well formed, smooth leaves. Well leafed.
No blooms or pods, plants prostrate.	Blooms and pods well represented.
Obviously would not mature.	In process of maturing.

TABLE II

Quantitative results (averaged) on various morphological features of bean plants started under (a) red filter for 7 days and 14 days, (b) under full light for the same lengths of time, then all followed by full light

Third Planting

Featured compared	7 Days Antho-red	14 Days Antho-red	7 Days Full Light	14 Days Full Light
Root length	33.9 cm	29.4 cm	41.8 cm	24.8 cm
Root dry weight	.6364 gm	.4837 gm	.8902 gm	.3274 gm
Length to 1st node	18.8 cm	20.4 cm	16.45 cm	15.9 cm
Length 1st to 2nd node	7.4 cm	8.5 cm	7.75 cm	8.5 cm
Entire stem length	43.5 cm	46.75 cm	40.0 cm	39.1 cm
Dry weight of stem	.7694 gm	.6446 gm	.6046 gm	.5096 gm
Stem diameter middle 1st internode	3.2 mm	3.4 mm	3.12 mm	3.2 mm
Pods per plant	1.8	1.0	1.8	1.6
Dry weight pods	.6676 gm	.3486 gm	.2438 gm	.6088 gm
Leaves per plant	15.8	14.75	15.2	11.4
Leaf area per plant	25.96 sq. in.	19.13 sq. in.	19.8 sq. in.	18.22 sq. in.
Dry weight of leaves	.7285 gm	.6468 gm	.5651 gm	.4518 gm
Weight total parts	2.8019 gm	2.1237 gm	2.3127 gm	1.8976 gm

All plants were incubated 72 hours for sprouting and all plants were processed for data after a total of 68 days of growth.

CHLOROPHYLL THERAPY AND ITS RELATION TO PATHOGENIC BACTERIA

By Mabel M. Esten and Albert G. Dannin

Although the green parts of plants have been used in the treatment of various diseases for many centuries, it was not until the scientific investigations of Willstaetter and Stoll in 1913 (10) that actual proof of the worth of such remedies began to be found. The close similarity of the chemical character of the chlorophylls found in the chloroplasts of green plants to that of the hemoglobin in human blood led to the theory that the chlorophylls might be the factors in green plants which give them therapeutic value, so a great deal of scientific investigation has been undertaken in laboratories, hospitals and in the private practices of many physicians to determine the efficacy of chlorophyll therapy. Many reports of excellent results in treatment of various diseases with chlorophyll were made in scientific publications and medical journals prior to 1940, but research and applications of the results have been greatly accelerated since that date. Professors and physicians in medical and dental colleges and in private practices have cooperated with manufacturers of chlorophyll preparations and derivatives, and the results of their work are shown in a large number of reports in medical and dental journals. Much of this research, accompanied by relief and cure for hundreds of patients, has been due to the efforts of the Rystan Company of Mount Vernon, New York, who have furnished chlorophyll preparations to physicians and research workers, under the trade name of Chloresium. Although it is not the purpose of this paper to discuss fully all the results gained during the years since 1913, a few statements will be made as to the general therapeutic uses of chlorophyll preparations.

Chlorophyll and its derivatives are used primarily in the form of ointments or liquids in a hydrophilic or an oil base, with variations to meet the therapeutic need. It should be emphasized that these preparations are not the direct extract from green plants but are derivatives of chlorophyll. In Chloresium products, for example, only the water soluble derivatives of chlorophyll A are used, chiefly in a hydrophilic base. In the natural state chlorophyll occurs in a colloidal form but

it is amorphous when isolated, and is ordinarily secured in a crystalline form for medicinal use. The preparations are applied topically, orally or systemically. In both topical and oral treatments they are used as wet dressings, ointments, irrigations and sprays. The systemic treatments are chiefly by means of packings, sprays and direct internal injections.

In the medical fields the following are the main types of diseases treated with chlorophyll preparations: cysts, ulcers and tumors of various kinds, wounds, burns, anal fistulae, ulcerative colitis, diseases of the perineal cavity, bed sores, gynecological and orthopedic conditions, ear, nose and throat infections, dermatoses, anemia and carcinoma. In dentistry the following have been treated with chlorophyll: Vincent's stomatitis, gingivitis, osteomyelitis, pyorrhea, post-operative conditions, malodorous breath and conditions requiring peridontal sepsis. A few of the outstanding results of chlorophyll therapy are the rapid acceleration of healing, rapid and sustained proliferation of normal tissue cells, formation of healthy granulation tissue, reduction of bacterial action, relief from pain, itching and burning, and the deodorization and clearing of malodorous suppurative conditions.

Chlorophyll products are apparently non-toxic, which gives them great advantage over many other substances. However, Burgi (3) reported in 1932 that cyanosis might be caused by extremely large internal doses of chlorophyll and that a cumulative effect might also occur. Becker (1) gave a report of one patient who showed a sensitivity to an isotonic solution of chlorophyll used as nasal packs in the treatment of sinusitis, but the absence of control conditions make this inconclusive. An extensive search of literature on the subject of chlorophyll therapy does not reveal any other reports of toxicity reactions and the concensus of opinion of all other writers is that chlorophyll preparations are completely non-toxic. Hein and Shafer (7) state that there are no toxic complications and the preparations may be used safely in concentrations up to 2% in the oral cavity. Gruskin (6) reports cases in which as much as 250 cc of a chlorophyll preparation was given intravenously for a period of six days without any toxic reactions whatever. Smith (9) states that 240 cc of a 2% solution was given orally for three days to a normal healthy male volunteer and there was no toxic effect. He also reports a case of subacute bacterial endocarditis in which 400 cc of a 0.5% chlophyll solution was given daily for eight days, with no toxic symptoms appearing at any time.

The excellent results gained in the treatment of various conditions in which pathogenic bacteria are involved have raised the question as to the exact relation of chlorophyll to the causal organisms. Impetus to research has been greatly stimulated by the work of Gruskin (6) and his colleagues at Temple University. Chlorophyll solutions and ointments prepared by the Department of Experimental Pathology at Temple University were used in the treatment of more than 1200 cases of "widely diverse character, ranging from acute infections of the upper respiratory tract and accessory sinuses to chronic ulcerative lesions of various types associated with varices, sinuses, and fistulae." Some cases were in the fields of proctology, gynecology, surgical infections, ear, nose and throat infections, and others were simple and complex dermatoses. Ulcerative carcinoma with much putrefaction and foul odor was cleared very promptly of odor and the chlorophyll preparation also stimulated production of connective tissue. The prompt relief from the odors of such suppurative diseases led Gruskin to conclude that chlorophyll has an apparent bactericidal effect upon the various pathogenic bacteria, although not actually bactericidal. He suggests that chlorophyll increases the resistance of cells in some physio-chemical manner so that enzymatic digestion of the cell membrane by invading bacteria or their toxins is checked, and that bacteria may be inhibited from forming their toxic compounds by the chlorophyll action. Since chlorophyll has the ability in the living cell where it is produced to break down carbon dioxide and free oxygen, he believes it may have the same action in the medicinal preparation and thus inhibit the action of anaerobic bacteria which cause malodorous lesions. Gruskin also reports a case of streptococcic septicemia which had an uneventful recovery with the sole use of chlorophyll derivatives. In a case of subacute bacterial endocarditis, the blood cultures remained negative for the bacteria as long as the patient received chlorophyll but became positive again after the treatment had been discontinued for three days, evidently as a result of a continuous discharge of septic emboli into the circulation. As a result of his experiments, Gruskin concludes that chlorophyll preparations do not have a definite bactericidal effect but do have some bacteriostatic effect, apparently by the stimulation of cells and tissues and the creation of adverse environmental conditions for the bacteria. However, he believes there may be a more direct action.

Goldberg (5), in a study of 300 dental cases, reports that odors due to anaerobic bacteria invariably disappear with a few chlorophyll applications, and he attributes this result to the oxidizing properties of chlorophyll. In cases of Vincent's stomatitis he came to the conclusion that chlorophyll therapy is almost a specific against the fusiform bacillus and the spirillum responsible for this condition. His results, however, seem to indicate a bacteriostatic and not a bactericidal action.

Rapp (8) reported a study of the effect of a chlorophyll preparation on the *Lactobacillus acidophilus* count in human saliva. Twenty-six per cent of the subjects had a negative count at the end of ten days, 42% at the end of the fourth week, and 90% at the close of the twenty-sixth week of the experiment. The results in the control group of subjects who had used other normal oral hygiene procedures showed a slight reduction in count, but not of any significant value. While there is some question of the relation of *Lactobacillus acidophilus* to tooth decay, there seems no reason to doubt that chlorophyll does have an inhibiting effect upon the organism. The report does not attempt to explain the action of chlorophyll upon this particular pathogen.

Carpenter (4) has recently investigated the use of chlorophyll preparations clinically in a carefully selected and controlled series of cases. One outstanding result of his study is that the wounds which were resistant or slow in healing or failed entirely to heal contained a form of bacteria which he calls *"Pseudomonas aerogenes."* The percentage of failures, however, was remarkably low. Carpenter concluded that chlorophyll is bactericidal in vitro in large concentrations but that its action in vivo is by means of its stimulating effect upon tissue cells rather than as a direct bactericidal agent.

Bowers (2) records his own experiences and those of more than thirty officers of the surgical service in an army hospital in the treatment of various types of cases with water-soluble derivatives of chlorophyll. He states that "they possess direct antibacterial activity, especially in relation to the secondary saprophytic, proteolytic organisms associated with wound infection, which give rise to the foul odor associated with this type of lesion." He concludes that the action is actually bacteriostatic and that its beneficial effect is by means of stimulation of host cells instead of direct action against the bacteria themselves.

Smith (9) conducted experiments both in vitro and in vivo in an effort to determine the action of chlorophyll preparations upon various diseases, using a saponified metal complex derivative, such as sodium copper chlorophyllin, which was provided in a saline solution in strengths ranging from 0.2% to 5% and also as ointments in lanolin, cholesterol and hydrophyllic bases. His preliminary studies indicated that chlorophyll alone in dilutions of from 1:100 to 1:500 would not support the growth or viability of staphylococci, streptococci or coliform bacteria over a period of twenty-four to forty-eight hours. There was a definite bacteriostatic effect upon the growth of these organisms when dilutions up to 1:2000 were used in a broth medium, but growth was not completely inhibited in this medium beyond a 1:5000 dilution. The deodorization and clearing of such infected, ulcerated lesions as carcinoma and varicose ulcers in a short period led Smith to conduct experiments in vitro to attempt a determination of the action of the chlorophyll derivatives upon the causal organisms. He used eight pathogens with various dilutions of chlorophyll, with veal infusion and one per cent amigen broth as media. The innoculations averaged about 9000 colonies, except in the case of the two anaerobes in which 1000 colonies were used. Inhibition of growth was noted in *Escherichia coli* and *Pseudomonas pyocyaneus* in 1:50 dilutions; in *Streptococcus mastitidis,* two strains of *Streptococcus hemolyticus, Clostridium perfringens* and *Clostridium histolyticum* in 1:1600 dilutions; and there was no inhibition of the growth of *Staphylococcus aureus.* Repeated experiments indicated that chlorophyll might have an action which interferes with the oxidation-reduction mechanism of anaerobic bacterial respiration, which might explain its bacteriostatic and even bactericidal effect in clinical cases. As a result of his studies, Smith states that the ordinary pathogenic bacteria will not survive for twenty-four hours in a simple isotonic saline solution of chlorophyll up to dilutions of 1:5000, which seems to be due to an oxidation action. The experiments on the more common pathogenic bacteria indicate that there is no direct action but bacterial growth is inhibited as a result of the production of an unfavorable environment. Smith states that "chlorophyll is not strictly bactericidal but that it does exert a definite bacteriostatic and even a bactericidal effect under suitable environmental conditions."

In brief summarization, it may be stated that investigations and experiments in chlorophyll therapy and in laboratory research indi-

cate that strong solutions of chlorophyll preparations have a bactericidal action on some pathogenic bacteria in vitro. However, in vivo, the effect seems bacteriostatic rather than bactericidal, chiefly through the action of the chlorophyll in stimulating tissue cells and creating an environment unsuitable for bacterial growth. The ability of chlorophyll to release oxygen is cited as a possible cause of the inhibition of anaerobic bacteria which are particularly active in suppurative diseases. Research to date indicates that chlorophyll has a definite place in the treatment of diseases caused by bacteria, but further research is necessary to determine the exact nature of the effect of chlorophyll upon the causal organisms.

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THE GENUS LIATRIS IN INDIANA

By CARL O. KELLER

In checking over specimens of Liatris Schreb. from the herbaria of
Dr. Chas. C. Deam and of Butler University, it was found that a con-
siderable degree of confusion and uncertainty has existed with regard
to the classification of these plants. This was to be expected, since
this genus is one of unusual complexity with many variables and
intergradations existing among the various species. Some attempts
at classification have been somewhat superficial, placing a number of
different types under one species name, while others have drawn the
line too closely and made separate species and varieties out of plants
which were merely mutations or impoverished individuals.

Another difficulty has been that of detecting the characters which
show a sufficient and regular degree of difference to justify separa-
tion into separate species. Such characters as pubescence of stem and
leaves, or the color of the pappus or the phyllaries, are of little value
in determining differences, since these qualities do not run true.
They may vary with the age and maturity of the plant or with the
conditions under which it grew.

There are four species of Liatris found in Indiana which even the
amateur taxonomist can learn to identify at sight, without any minute
examination of flowers, phyllaries, etc. These are: *Liatris spicata*
var. *typica, L. pycnostachya, L. cylindracea,* and *L. squarrosa.* The
distinguishing characteristics of these four are quite obvious. The
other species, however, run into the *L. scariosa complex* and are more
difficult to classify. Gaiser[1] has produced a valuable piece of work
which simplifies the classification of this group for the North Ameri-
can continent generally, but since many of the species described in
this study are not found in Indiana, or even in the mid-western states,
there seems to be a need for a simpler key to serve particularly be-
ginning students of taxonomy in this area.

The key presented in this study is based on the minute examina-
tion of some three hundred specimens which were collected within

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[1] Gaiser, L O., The Genus Liatris, Rhodora 48, Aug.-Dec. 1946.

the boundaries of Indiana, together with careful comparisons between the data thus derived and the data presented in Gaiser's study. Of the rarer varieties, only a few specimens were available for study, but for the more common types the characters of forty or fifty specimens were charted and summarized. The following specimens were iso-types of some reported in Gaiser's study: Deam 1243, 5408, 20900, 20918, 20934, 21038, 21084, 21342, 21889, 22429, 22432, 22461, 23994, 24374, 56936; Butler 40697, 50591, 56319, 62289, 67717, 67718, 70431, 70434, 70436, 70439, 70440, 70444, 70450.

The following factors were considered in seeking clues for clas-sification of these plants and for constructing the simplified key: rootstock, habitat, height and thickness of stem, appearance of stem, length and width of leaves, structure and appearance of leaves, length and type of inflorescence, size and shape of heads, number of flowers per head, length and appearance of corolla, length of achene, length and appearance of pappus bristles, size and shape of involucre, size and shape of phyllaries, and the general appearance of the phyllaries. The difference between the barbellate and plumose pappus divides the genus into two sections, *Suprago* and *Euliatris*. Of the latter section only two species occur in Indiana, viz., *L. cylindracea* and *L. squarrosa* var. *typica*. The other species with the barbellate pap-pus are of the Suprago section. Of these, eleven species and varieties have been found in the state.

KEY TO SPECIES AND VARIETIES OF LIATRIS IN INDIANA

1. Pappus barbellate, with lateral cilia on seta scarcely visible to the naked eye 2
1. Pappus plumose, its feathery appearance obvious to the naked eye........ 6

    2. Heads 5-25-flowered. Phyllaries mostly erect. Inflorescence a thickly crowded spike of small, somewhat cylindrical heads. Corolla tube non-pilose within 3
    2. Heads 15-75-flowered, turbinate-cylindrical to sub-globose in shape. Phyllaries erect, puckered, or partially recurved, with obtuse or rounded tips. Corolla tube pilose within 4

3. Leaves linear-lanceolate; heads 10-18-flowered; phyllaries obtuse and erect ....*spicata v. typica* (1)
3. Leaves definitely lanceolate; heads 20-25-flowered; phyllaries obtuse and erect ....*X Steelei* (2)
3. Leaves linear; heads 5-12-flowered; phyllaries acute to acuminate and recurved at tips. Usually colored...................*L. pycnostachya* (3)

DESCRIPTION OF SPECIES

1. LIATRIS SPICATA (L.) Willd. var. TYPICA Gaiser. (Liatris spicata of Deam's *Flora of Indiana*). HABITAT: Mostly wet, boggy or marshy places; ditches and ravines. Also found along railroads, on sand dunes, in open fields and clearings, and along roadsides. ROOTSTOCK: Globose to enlarged and shallow, depending on the age of the plants. In older plants much vegetative reproduction takes place due to the separation of the parts of the rootstock. STEM: Tall and sturdy, 6-13 dm. high, 3-6 mm. thick just above the ground, entirely glabrous with few exceptions. LEAVES: Lower cauline leaves linear to lanceolate, 10-35 cm. long, 3-16 mm. wide, becoming smaller as they ascend the stem; glabrous above, glabrous to pubescent below. INFLORESCENCE: 7-60 cm. long, in most cases a dense spike. HEADS: 9-15 mm. long, 5-10 mm. wide; cylindrical in shape. FLOWERS: 5-11 per head. COROLLA: 5-7 mm. long, phlox-purple, sometimes white; non-pilose within the tube. ACHENE: 3-5 mm. long. PAPPUS: 5-7 mm. long; barbellate, 30-50 setae. INVOLUCRE: 6-12 mm. long, 4-8 mm. wide; appressed and sometimes adherent. PHYLLARIES: 2-10 mm. long, 1-3 mm. wide; glabrous, mostly green at time of flowering; margins narrow and scarious; tips erect and obtuse. DISTRIBUTION:

New York to Florida and westward to the Mississippi River; Ontario and upper Michigan to the Gulf of Mexico. Indiana counties: Lake (D, B); Porter (B); LaPorte (B); Elkhart (D); Steuben (B); Starke (D, B); Marshall (D); Noble (D), B); Pulaski (B); Allen (D); Newton (B); Jasper (B); White (B); Greene (B); Cass (D, B); Tippecanoe (D, B); Montgomery (B); Henry (B); Randolph (D, B); Clay (B); Clarke (D); Crawford (D); Posey (B); Perry (B). Also reported from Tipton Co. (D).

2. X LIATRIS STEELEI Gaiser (*L. spicata* x *sphacroidea*) (*L. spicata,* in part, of Deam's *Flora of Indiana.*) HABITAT: Sandy dunes. ROOTSTOCK: compressed, 3 cm. wide, 2 cm. high. STEM: erect, 8-11 dm. high, glabrous. LEAVES: lower cauline leaves 9-20 cm. long, 7-15 mm. wide; linear to lanceolate, becoming abruptly reduced as they ascend the stem. INFLORESCENCE: loose spike; 12-40 cm. long. HEADS: sub-turbinate; 10-17 mm. long, 9-12 mm. wide. FLOWERS: 12-25 per head. COROLLA: phlox-purple; 5-7 mm. long. ACHENE: 4-5 mm. long. PAPPUS: 6-7 mm. long; barbellate, 36-38 setae. INVOLUCRE: 10-13 mm. long, 10-11 mm. wide; appressed. PHYLLARIES: 2-10 mm. long, 1-4 mm. wide; glabrous, somewhat herbaceous, ovate to oblong in shape; margins narrow and scarious. DISTRIBUTION: Northern limit of the range of *L. spicata* var. *typica.* Indiana—Lake Co. (D, B). Also reported from Porter Co. by E. S. Steele.

3. LIATRIS PYCNOSTACHYA Michx. (*L. Bebbiana* of Deam's *Flora of Indiana.*) HABITAT: prairie lands, along railroads and roadsides, open wooded hillsides, sandy, peaty soil. ROOTSTOCK: enlarged and woody, up to 1 dm. in width. (Globose in young plants.) STEM: stiff and striate; usually hairy to hirsute, sometimes glabrous; 7-15 dm. tall, 4-6 mm. thick at base. LEAVES: lower cauline linear, 9-20 cm. long, 3-12 mm. wide; mostly glabrous, some hairy to hirsute; reducing to subtending bracts as they reach the top of the stem. INFLORESCENCE: dense, crowded spike; 6-20 cm. long. HEAD: 6-13 mm. long, 3-8 mm. wide; cylindrical. FLOWERS: 5-12 per head. COROLLA: 6-9 mm. long; pilose or hairy within the tube. ACHENE: 3-7 mm. long. PAPPUS: 6-8 mm. long; barbellate, 32-50 setae. INVOLUCRE: 6-11 mm. long, 4-7 mm. wide; spreading. PHYLLARIES: 2-8 mm. long, 1-2 mm. wide; squarrose or reflexed, with tips ciliate or crisped, acute to acuminate. DISTRIBUTION: Indiana and South Dakota to Louisiana and Texas. Indiana counties: Newton (D, B);

Benton (D, B); Vigo (D, B); Bartholomew (B). Also reported from Jasper Co. by T. N. Coulter.

Regarding the matter of dividing this species into two groups, *L. pycnostachya* and *L. Bebbiana,* Gaiser, (p. 243) states: "Rydberg (Brittonia 1; 99 (1931) described *L. Bebbiana* from Illinois, stating 'it was related to *L. pycnostachya* but the outer bracts are ovate and merely acute, not lanceolate and long acuminate.' A detailed study of this type specimen (M. S. Bebb, Fountaindale, Winnebago Co., Ill., (NY), has failed to disclose how this or any other fundamental character can separate it from *L. pycnostachya* Michx."

4. LIATRIS SCABRA (Greene) K. Schum. (*L. scariosa,* in part, of Deam's *Flora of Indiana*). HABITAT: Old fields, rocky slopes, sparsely wooded knobs. ROOTSTOCK: rounded; 2 cm. or more in diameter. STEM: scabrous; 6-12 dm. high, 4-7 mm. thick toward base. LEAVES: scabrous on both surfaces; lower cauline oblanceolate, 9-25 cm. long, 11-40 mm. wide. INFLORESCENCE: open spike or raceme, rarely a panicle; 10-60 cm. long. HEADS: cylindrical, turbinate, or globose; 15-18 mm. long, 14-16 mm. wide. FLOWER: 18-34 per head. COROLLA: 8-12 mm. long; pilose within the tube. ACHENE: 4-5 mm. long. PAPPUS: 7-10 mm. long; barbellate, 28-36 setae. INVOLUCRE: 8-12 mm. long, 10-15 mm. wide. PHYLLARIES: herbaceous; pubescent or scabrous; with erect, obtuse and ciliolate tips; 2-10 mm. long, 1-3 mm. wide. DISTRIBUTION: Ohio to Illinois south to Alabama and west to Arkansas and Oklahoma. Indiana counties: Kosciusko (D, B); Vigo (D, B); Franklin (B); Sullivan (B); Brown (D); Washington (D, B); Clarke (D, B); Perry (B); Spencer (B); Crawford (D, B); Harrison (D, B). Also reported from Cass Co. by C. M. Ek, and from Jackson Co. by Kriebèl.

5. X LIATRIS NIEUWLANDII (Lunell) Gaiser. (*L. scariosa,* in part, of Deam's *Flora of Indiana.*) HABITAT: sandy, gravelly soil along roadsides, railroads, and hillsides. ROOTSTOCK: rounded, somewhat shallow. STEM: glabrous or slightly pubescent below, densely pubescent above; 8-14 dm. tall, 4-8 mm. thick toward base; very stiff. LEAVES: more or less pubescent on both surfaces, sometimes glabrous; lower cauline 12-20 cm. long, 10-30 mm. wide. INFLORESCENCE: few to numerous large heads; usually pedicellate; 6-45 cm. long. HEADS: 13-25 mm. long, 12-26 mm. wide; globose to hemispheric. FLOWERS: 24-75 per head. COROLLA: 7-11 mm. long; generally non-pilose, though sometimes having a few hairs within the tube. ACHENE: 5-6

mm. long. PAPPUS: 7-10 mm. long; barbellate, 26-34 setae. IN-
VOLUCRE: 10-15 mm. long, 14-24 mm. wide. PHYLLARIES: 2-14 mm.
long, 1-4 mm. wide, erect; mostly green to the margins which are
finely ciliolate. DISTRIBUTION: Indiana to Missouri and north to
Wisconsin and Michigan. Indiana counties: Porter (B); LaGrange
(D); Steuben (D, B); Noble (D, B); Kosciusko (D, B); Allen
(D); Cass (B); Marshall (B).

6. LIATRIS EARLEI (Greene) K. Schum. (*L. scariosa,* in part, of
Deam's *Flora of Indiana.*)

Gaiser reports only one specimen of this species from Indiana,
namely Deam-22429, from Harrison Co. She also lists this same
specimen number under L. scabra. An examination of an isotype of
this plant did not reveal any characters which would justify separat-
ing it from the scabra group. Having no other specimens available
for examination, and since it is quite likely that this species might be
found in the state, we quote Gaiser's description:

"*Liatris Earlei* (Greene) K. Schum. Corm small, sub-globose,
ca. 2 cm. in diameter; stem usually single, 4-9 dm. high, often some-
what virgate, softly and densely pubescent, or asperous with short
white hairs, or even almost glabrous; leaves glabrous, softly pubescent
and rough on the margins only, or more rarely scabrous, the basal
sharply lanceolate, 10-20 cm. long, 5-15 cm. wide, subpetiolate, nar-
rowing to a short- or longer-winged petiole from one third to one
half the length of the blade, the upper rigid, sharp-pointed, narrowly
lanceolate or linear, reduced from 6-8 cm. long to narrow bracts less
than 1 cm. subtending the heads; inflorescence narrowly racemose,
of 20-50 subsessile heads on erect or depressed pedicels about as long
as the heads, or more rarely branched and paniculate by the elongation
of the pedicels into slender peduncles bearing several heads each;
heads of 15-25 flowers, somewhat turbinate or campanulate, 1-1.5 cm.
long and ca. 1 cm. wide when flowers are open; phyllaries appressed
or sometimes recurved, herbaceous, green and softly pubescent, with
cilolate but almost non-scarious margins; outer phyllaries subovate;
middle and inner ones oblong-spatulate, 7-4 mm. long and 2-3 mm.
wide, herbaceous and usually finely pubescent, sometimes with pur-
plish ciliolate margin; corolla-tube 7-9 mm. long, scantily to moder-
ately pilose at the base of the tube; mature achene 3-4 mm. long;
pappus about 6 mm. long, barbellate." DISTRIBUTION: Abundant

from Tennessee to Alabama. Ocasionally found North Carolina to Florida and Indiana to Louisiana and Texas.

7. LIATRIS ASPERA var. TYPICA Gaiser (*L. scariosa,* in part, of Deam's *Flora of Indiana.*) HABITAT: sandflats; along railroads and roadsides. ROOTSTOCK: sub-globose to irregular, 2-5 cm. in diameter. STEM: 4-11 dm. high; single or several; stout, rough-puberulent above, usually hairy throughout. LEAVES: linear-lanceolate, asperous; 10-15 cm. long and 1-2 cm. wide along lower part of stem, reducing upward. INFLORESCENCE: a long, loose spike; 30-50 cm. long. HEADS: 15-25 mm. long, 15-20 mm. wide; globose. FLOWERS: 25-40 per head. COROLLA: 8-10 mm. long; usually purple, sometimes white; pilose within tube. ACHENE: 4-6 mm. long. PAPPUS: 7-8 mm. long; barbellate, 25-40 setae. INVOLUCRE: 10-14 mm. long, 10-13 mm. wide; having a puckered appearance. PHYLLARIES: glabrous; 3-10 mm. long, 1-3 mm. wide; oblong-spatulate to rounded; decidedly bullate or puckered; tips rounded with broad scarious margins. DISTRIBUTION: central states, Ohio to Minnesota south to Louisiana and Texas. Indiana: Jasper Co. (B). Also reported from Porter Co. by E. S. Steele.

8. LIATRIS ASPERA var. INTERMEDIA (Lunell) Gaiser. (*L. scariosa,* in part, of Deam's *Flora of Indiana.*) HABITAT: dunes, sandy clearings and lake borders, along railroads and roadsides. ROOTSTOCK: rounded, irregular. STEM: glabrous below with appressed hairs above; 4-11 dm. high, 4-7 mm. thick toward base. LEAVES: glabrous with few exceptions; 9-30 cm. long, 6-32 mm. wide at lower part of stem, becoming smaller upward. INFLORESCENCE: long open spike, 10-60 cm. long. HEADS: somewhat globose; 13-20 mm. long, 11-20 mm. wide. FLOWERS: 18-40 per head. COROLLA: 7-10 mm. long; usually purple, rarely white; pilose within the tube. ACHENE: 4-8 mm. long. PAPPUS: 5-8 mm. long; barbellate, 32-42 setae. INVOLUCRE: 10-14 mm. long, 10-17 mm. wide; puckered in appearance. PHYLLARIES: 3-12 mm. long, 1-4 mm. wide; glabrous with broad rounded tips and scarious margins, loose and strongly bullate or puckered. DISTRIBUTION: from the Mississippi River eastward to North Carolina and south to Florida, also westward from Missouri to Texas. Indiana counties: Lake (D, B); Porter (D, B); LaPorte (B); Elkhart (D, B); LaGrange (D, B); Steuben (D, B); Starke (D, B); Marshall (D); Newton (D, B); Jasper (B); Pulaski

(B) ; Benton D, B) ; White (B) ; Cass (B) ; Crawford (D) ; Harrison (B).

9. X Liatris sphaeroidea Michx. (*L. scariosa,* in part, of Deam's *Flora of Indiana.*) Rootstock: irregular to sub-globose. Stem: one to several; 4-11 dm. tall, 4-6 mm. thick at base. Leaves: glabrous, pubescent or asperous; linear to lanceolate; 10-15 cm. long, 8-12 mm. wide on lower part of the stem, reducing upwards. Inflorescence: raceme or panicle. Heads: barely globose; 13-25 mm. long, 12-24 mm. wide. Flowers: 25-40 per head. Corolla: usually purple, sometimes pink, rarely white; pilose within the tube. Achene: 4-6 mm. long. Pappus: 7-8 mm. long; barbellate. Phyllaries: loosely erect; slightly puckered, with narrow scarious margins. Distribution: Michigan to Nebraska southward to Tennessee and Arkansas. Indiana counties: Steuben (D) ; Lake (D) ; also reported from Porter Co. by E. S. Steele.

10. Liatris cylindracea Michx. Habitat: sand ridges, dunes and prairies. Rootstock: rounded, up to 3 cm. in diameter. Stem: 3-6 dm. tall, 2-4 mm. thick at base; usually glabrous, sometimes with few hairs. Leaves: linear; mostly glabrous, lower cauline 15-30 cm. long, 3-6 mm. wide. Inflorescence: loose raceme; 5-20 heads; 7-20 cm. long (rarely occurring with single heads). Heads: cylindrical; 18-20 mm. long, 8-10 mm. wide. Flowers: 20-60 per head, seldom more than 35. Corolla: 10-14 mm. long; purple, rarely white; inner surfaces hairy. Achene: 4-6 mm. long. Pappus: 8-10 mm. long; plumose, 18-24 setae. Involucre: 12-18 mm. long, 8-10 mm. wide; herbaceous; appressed. Phyllaries: 4-12 mm. long, 1-4 mm. wide; glabrous; ovate and rounded at top with acuminate or mucronate tips. Distribution: western New York to Minnesota and Missouri. Indiana counties: Lake (D, B) ; Porter (D, B) ; LaPorte (B) ; Elkhart (B) ; LaGrange (D) ; Starke (D) ; Newton (B) ; Tippecanoe (D, B).

11. Liatris squarrosa (L.) Michx. var. typica Gaiser. (*L. squarrosa* of Deam's *Flora of Indiana.*) Habitat: roadsides, dry knobs and fields. Rootstock: rounded; up to 4 cm. in diameter. Stem: 4-10 dm. tall, 3-7 mm. thick at base; pubescent with short dense white hairs. Leaves: linear and rigid; usually pubescent though sometimes glabrous; 12-20 cm. long, 4-10 mm. wide. Inflorescence: 10-40 cm. long; one or a few heads to a many-headed

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raceme. HEADS: cylindrical to turbinate; 20-25 mm. long, 12-20 mm. wide. FLOWERS: 20-40 per head (terminal head up to 60). COROLLA: 10-18 mm. long; phlox-purple; inner surface hairy. ACHENE: 4-6 mm. long. PAPPUS: 12-14 mm. long; plumose, 16-26 setae. INVOLUCRE: broad and squarrose; 15-18 mm. long, 12-15 mm. wide. PHYLLARIES: 9-18 mm. long, 1-3 mm. wide; glabrous to hairy, with ciliate-membranous margins and acute to acuminate squarrose tips. DISTRIBUTION: Delaware to Florida westward to Alabama and Missouri. Indiana counties: Daviess (D); Clark (D, B); Perry (D); Crawford (D); Harrison (D, B); Floyd (B).

A CONSIDERATION OF *GOMPHONEMA PAR-VULUM* KÜTZ

By John H. Wallace[1] and Ruth Patrick[1]

This is a study of the variability of *Gomphonema parvulum Kütz.* During the summer of 1948, a biological survey of the Conestoga River Basin in eastern Pennsylvania was conducted by the Academy of Natural Sciences of Philadelphia which aimed at the establishment of biological standards for determining the health of a stream.

In all, over 600 collections of diatoms were made. From the study of these collections, new evidences of affinities between several species were found and the wide variability of certain species especially was noted. *G. parvulum Kütz.* was particularly troublesome because of its high degree of variability and exceedingly common occurrence. One collection, taken from a portion of a diatom bloom on one rock in Muddy Creek below Adamstown, Pennsylvania, showed an almost unialgal, highly variable, intergrading population, of *G. parvulum* Kütz., the range of variation being so great as to embrace five named varieties. This type of variation was found not only here, but in most of the exsiccatae and slides which the authors examined labeled as *G. parvulum* Kütz., or one of its named varieties. In each case, the designated variety showed a great deal of variation which intergraded into the typical form of the species and often intergraded into other species of *Gomphonema*.

The origin of such a highly variable taxon can only be conjecture. However, some mechanism must exist whereby the variants are able to continue as a mixed population. Assuming that a morphological variation implies physiological differences, the expected result over a period of time would be that one variant should be able to gain dominance over another variant. Considering light conditions to be similar throughout the habitat, one plausible explanation of the maintenance of such a highly variable taxon is that the constant flow of water over the habitat insures a continuous replenishment of nutrients, thus eliminating any competition of the variants for nutrients.

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[1] Limnology Department, Academy of Natural Sciences of Philadelphia and Department of Botany, University of Pennsylvania.

While it is true that in no stream is the concentration of the various nutrients constant, it nevertheless varies about a mean, and the nutrient requirements of all forms must lie within the limits of variation or the individuals would be eliminated from the habitat. Furthermore, this variation of nutrients would mean that conditions at one time would be more favorable to one variant, and at some other time, more favorable to another. Thus the number of individuals of a given variant might vary from time to time, but the variant would always remain as a part of the population. The importance of this continual renewal of nutrients, varying somewhat in concentration, in the maintenance of a highly variable taxon is further substantiated by the fact that almost all the highly variable taxons are usually found in streams and not in still waters.

At first an attempt was made to delimit or define the named varieties of *G. parvulum* Kütz. In so doing, all original descriptions of the varieties were checked, using isotype material wherever possible. A separation of the varieties along clear-cut lines proved impossible for several reasons. For one, in identification of varieties, authors often did not go back to original descriptions. For example, *G. micropus* Kütz. had become completely divergent from Kützing's original (1844) description and illustration. Secondly, the great amount of diatom literature and the difficulty in obtaining it often resulted in the same entity being described twice. In point, while Cleve (1893) never pictured *G. parvulum* var. *subelliptica,* his description so closely fits the description and picture of *G. parvulum* var. *curta* R. d'Aub. apud Heribaud (1920) that it is very evident that the latter should be considered synonymous with the former.

A study was made of all slides at the Academy of Natural Sciences of Philadelphia which were designated as having on them specimens of *G. parvulum* Kütz. or its varieties. It was found that one or more of the varieties generally occurred with the type. Hustedt, 1938, (Archiv. Hydrobiol. Suppl. Bd. 15, Bd. 7:434) has noted this variation in the case of two varieties of *G. parvulum* Kütz.

The named varieties almost always occurred as extremes of variation around the type, and the direction of variation seemed to have no geographical or ecological correlation. In the absence, on one hand, of demonstrable discontinuity between variants, and, on the other hand, of ecological or geographical correlations, the following varieties are reduced to synonymy.

Sphenella ? parvula was first described by Kützing in 1844. In 1849 Kützing recognized *Sphenella parvula* but also described *Gomphonema parvulum,* differentiating the latter on the manner of growth. Rabenhorst, 1853, placed *Sphenella parvula* under *Gomphonella parvula* and states it occurs in a jelly mass. Rabenhorst, 1864, Flora Europaea Algarum, p. 291, combined *Sphenella parvula* and *Gomphonema parvulum* of Kützing under the name *Gomphonema parvulum* and included also his *Gomphonella parvula*.

GOMPHONEMA PARVULUM KÜTZ. var. PARVULUM

> *Sphenella ? parvula* Kütz., 1844, Bacill., p. 83, pl. 30, fig. 63.
>
> *Gomphonella parvula* Rabenh., 1853, Sussw. Diat., p. 61.
>
> *Gomphonema parvulum* Kütz., 1849, Sp. Algarum, p. 65.
>
> *Gomphonema parvulum* var. *curta* R. d'Aub. apud Heribaud, 1920, Ann. Biol. Lacustre. 10 :73, pl. V, fig. 15.
>
> *Gomphonema parvulum* var. *exilis* Grun., 1878, Naturwiss. Beitr. Kenntniss Kaukasus. by O. Schneider, p. 107.
>
> *Gomphonema micropus* var. *exilis* Grun. apud Van Heurck, 1880,
>
> Syn. Diat. Belgique, pl. XXV, fig. 6.
>
> *Gomphonema parvulum* var. *exillisima* Grun. apud Van Heurck, 1880,
>
> Syn. Diat. Belgique, pl. XXV, fig. 12.
>
> *Gomphonema parvulum* var. *genuinum* f. *semiaperta* A. Mayer, 1928,
>
> Denkschr. Bayer Bot. Ges. Regensburg. 17 NF 11 : 104, pl. II, fig. 24.
>
> *Gomphonema parvulum* var. *lagenula* Freng., 1923, Bol. Acad. Nacion Ciencias Cordoba. 27 : 68, pl. VI, fig. 16.
>
> *Gomphonema lagenula* Kütz., 1844, Bacill., p. 85, pl. 30, fig. 60.
>
> *Gomphonema parvulum* var. *lanceolata* Grun. apud Van Heurck, 1880,
>
> Syn. Diat. Belgique, p. 125, pl. XXV, fig. 10.
>
> *Gomphonema parvulum* var. *micropus* Cl., 1894, K. Sv. Vet. Akad. Handl. 26(2) : 180.
>
> *Gomphonema micropus* Kütz., 1844, Bacill., p. 84, pl. 8, fig. XII.

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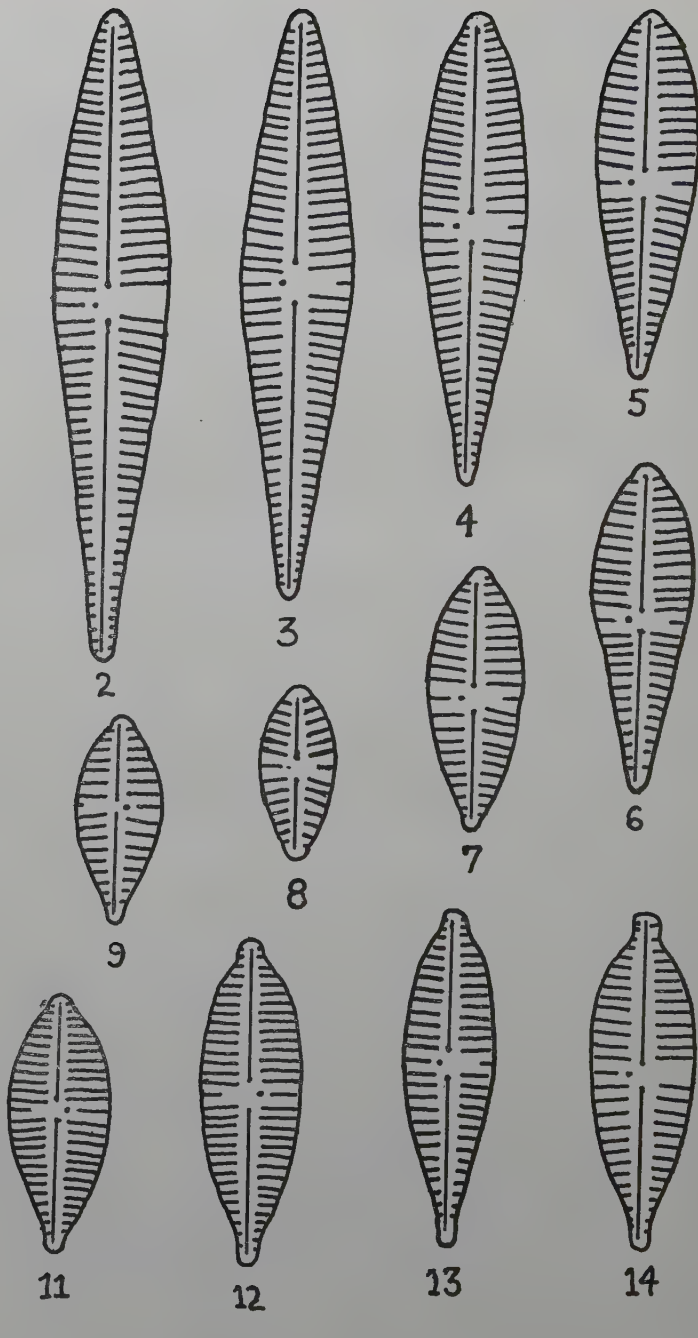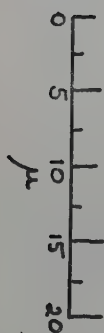
Gomphonema micropus var. *minor* Grun. apud Van Heurck, 1880, Syn. Diat. Belgique, pl. XXV, fig. 5.

Gomphonema micropus var. *major* Herib., 1903, Diat. Fossiles d'Auvergne, 2nd Mem., p. 21.

Gomphonema micropus forma *major* Grun. apud Van Heurck, 1880,

Syn. Diat. Belgique, pl. XXV, fig. 4.

Gomphonema parvulum var. *subelliptica* Cl., 1894, K. Sv. Vet. Akad. Handl. 26(2) : 180.

Gomphonema parvulum var. *subcapitata* Grun. apud Van Heurck, 1880,

Syn. Diat. Belgique, p. 125, pl. XXV, fig. 11.

This taxon includes all the variation in shape and striae number which occur around the more "typical" *G. parvulum* Kütz. One extreme of this variation seems to terminate in the short, elliptical *G. parvulum* var. *subelliptica* Cl. Figures No. 8, No. 9, and No. 19 would fit the description of this variety.

Another direction of variation is represented by *G. parvulum* var. *exillisima* Grun. as seen on Van Heurck Type Slide No. 220. This thin form with subcapitate bas and apex is merely an extreme in variation of *G. parvulum* var. *subcapitata* Grun. On Van Heurck Type Slide No. 17, Grunow lists both *G. parvulum* var. *subcapitata* Grun. and *G. parvulum* var. *exillisima* Grun.; the only discernable difference being that *G. parvulum* var. *exillisima* Grun. has a slightly greater length to breadth ratio.

Another extreme would appear to terminate in a form (Fig. No. 1) identical with *G. naviculoides* W. Sm., 1856, Brit. Diat. 2 : 98, as seen on slide No. 3438 of the Febiger Collection labeled "*Gomph. naviculoides,* Victoria Tank, Edinb. Botanic Garden, no. 332" which is the type locality of this species and which probably is some of William Smith's material. Since this diatom has an oblique raphe and since it is almost symmetrical, it is the authors' opinion that this should remain a variety of *G. gracile* Ehr. where it was placed by Cleve, 1894, K. Sv. Vet. Akad. Handl. 26(2) : 183. In other words, this extreme represents the connecting link between *G. parvulum* Kütz. and *G. gracile* Ehr. and the actual limit of *G. parvulum* Kütz.

var. *parvulum* should be that form which approaches *G. gracile* var. *naviculoides* Cl. but which is distinctly asymmetrical to the transverse axis and which does not show the oblique raphe (Fig. No. 2). Slide No. 1925 of the General Collection shows the same limit of variation, i.e., *G. gracile* var. *naviculoides* Cl., but in this case the variation goes through what appears to be *G. parvulum* var. *lanceolata* Grun. (Fig. 16). The variation, on the other hand, in Station 139, Collection No. 3, passes through a form which rather agrees with Kützing's original description of *G. micropus* (Fig. 5). It should be noted that Kützing's original description of *G. micropus* differs considerably from *G. parvulum* var. *micropus* Cl. which is supposed to be based on Kützing's species. Cleve and Grunow and subsequent authors have described and pictured a somewhat rostrate form, which is not the form pictured or described by Kützing. According to Grunow, Van Heurck Type Slide No. 218 shows *"Gomph. micropus passant au G. angustatum."* *G. angustatum* Kütz. is on the slide, but no diatom similar to *G. micropus* Kütz. as pictured in Van Heurck's Syn. Diat. Belgique can be found. We have been unable to find any authenticated specimen of Grunow's, but on the basis of his illustrations, it is evident that some mistake was made. *G. angustatum* Kütz. does intergrade into *G. parvulum* Kütz. var. *parvulum,* but the presence of the much broader capitate apex of *G. angustatum* Kütz. and the wide spaces around the central striae are distinctive enough characters on which to base a separation of the two species.

We have placed in synonymy *G. parvulum* var. *genuinum* forma *semiaperta* A. Mayer because the character, lack of shortened stria opposite the stigma, is to be found now and then on almost all forms of the *G. parvulum* var. *genuinum* A. Mayer taxon.

We have not seen material of the following varieties and the descriptions do not adequately treat the variability. We are unable to state with any certainty where they belong in this complex, and they are therefore merely listed below.

GOMPHONEMA PARVULUM var. AEQUALIS A. Mayer, 1928, Denkschr. Bayer Bot. Ges. Regensburg. 17 NF 11 : 104, pl. II, fig. 28.

A. Mayer's description of this variety is, "Schalen lanzettlich, Fuss- u. Kopfende geschnabelt-kopfig, 16-20μ lang, 5-6μ breit, fast symmetrisch zur Querachse." As pictured, this variety is so symmetrical that the authors certainly would not include it under *G.*

parvulum Kütz. var. *parvulum*. Our Fig. No. 23 is a photostat of the original figure.

GOMPHONEMA PARVULUM var. DESERTA Skvortzow, 1935, Publ. Mus. Hoangho Paiho de Tien Tsin. 36: 34, pl. 8, fig. 21.

This diatom is 15μ long, 6.8μ wide, with 15 striae in 10μ. Fig. No. 21 is a photostat of the original figure.

GOMPHONEMA PARVULUM var. FOSSILIS Lenoble, 1948, Mem. Acad. Malgache. p. 145, pl. I, fig. 11.

This variety is published without a description, but the picture is adequate, the shape and striae being distinctive. It was found in the fossil deposit of Aquitanien, which Lenoble dates as Pliocene. Fig. No. 24 is a photostat of the original figures.

GOMPHONEMA PARVULUM var. SINICA Skvortzow, 1935, Publ. Mus. Hoangho Paiho de Tien Tsin. 36 :26, pl. 6, fig. 11.

This diatom is described as being 25μ long, 6.8μ wide, and the striae 12 in 10μ. Fig. No. 22 is a photostat of the original figure.

GOMPHONEMA PARVULUM var. UNDULATA A. Cleve, 1895, Bihang Till K. Sv. Vet. Akad. Handl. 21 Afd. III(2) :21, pl. I, fig. 18.

Astrid Cleve-Euler's description of this variety is: "Valve tri-undulate, with rostrate ends, 0.02 mm. in length, 0.004 mm. in breadth. Axial and central areas indistinct. Striae 16 in 0.01 mm." The locality is Kvikkjokk. The authors have never seen a slide of this diatom, but there can be no question that it is not a member of the large *G. parvulum* Kütz. var. *parvulum* taxon. Fig. No. 20 was re-drawn to scale from the original drawing.

PHYCOLOGISTS OF INDIA[1]

By C. Mervin Palmer

In July 1947, the writer obtained a leave of absence from Butler University and went to India for a period of approximately two years. The trip was made under the auspices of the American Friends Service Committee in order to help in the work of relief and rehabilitation. It had been expected that most of the work would be in villages near Calcutta, but the rioting which occurred on a very large scale in the Punjab Province, in the autumn of 1947, made it necessary for the Quaker service unit to set up relief centers in several places in northwestern India and Pakistan. During this period there were occasional opportunities for the writer to meet with botanists in Lahore, Delhi and Calcutta.

Late in 1948, the writer was loaned by the Friends' unit to UNESCO (United Nations Educational, Scientific and Cultural Organization) Science Co-operation Office for South Asia which had just recently established its headquarters at Delhi, India. The duties as a Field Scientific Officer for UNESCO involved travelling throughout much of India to confer with scientists in the universities, colleges and government research laboratories. This afforded additional opportunities to meet the botanists, including algologists. It is a privilege to be able to report, at this time, on our co-workers in the field of phycology who are residents of India and Pakistan.

Calcutta is one of the centers of algological research. Dr. K. Biswas, who is Director of the Botanical Garden at Sibpur, near Calcutta, also teaches a course in algae at Science College of Calcutta University. He is the author of a number of papers on the algae of India and is at present preparing a check list of Indian algae. During 1947-49, he was president of the Botanical Society of Bengal.

Dr. M. T. Philipose, formerly a student of Dr. Iyengar at Madras, is now at the Inland Fisheries Research Station at Pulta, near Calcutta, where he expects to spend much of his time in studying the

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[1] Paper given at the Annual Meeting of the Phycological Society of the Americas held in New York City, December 27, 1949.

phytoplankton of streams and ponds. Mr. K. S. Srinivasan, who is also a former student of Dr. Iyengar, is Curator of the Industrial Section of the Indian Museum at Calcutta. Recently he has been much interested in the marine algae of the Bay of Bengal. The writer first met him at the Biological Station on Krusadai Island in south India where Mr. Srinivasan was collecting seaweeds. This marine station has been the best in the country and has excellent shores from which to collect. A new Central Government research station is being developed nearby.

Mr. J. C. Banerji is a member of the botany department of Science College, Calcutta, who is interested in a study of the freshwater algae. Dr. B. C. Kundu, who has published on the Charophytes of Bengal Province, is now Director of Jute Agricultural Research Institute at Hooghly, near Calcutta.

Another group of algologists has been centered at Banaras in United Provinces. Dr. H. Bharadwaja has been Head of the Botany Department of Banaras Hindu University. Not only has he published his own work on Indian Myxophyceae, but he has stimulated a number of students to study in the same field, including Dr. S. C. Dixit, who is now at Wilson College, Bombay. Dr. Bharadwaja recently has moved from Banaras to Jodhpur in Rajputana where he is Principal and Professor of Botany at Jaswant College.

At Banaras Hindu University, Dr. Ram Nagina Singh is a Lecturer in Botany and is permitted to spend most of his time on research. He is interested in the greens and blue-greens and has been particularly concerned with those which are of significance in rice fields. Graduate students specializing on algae at Banaras University include Mr. J. N. Misra, Mr. G. S. P. Rao, Mr. Y. S. R. K. Sarma and Mr. V. P. Singh.

While at Gauhati, Assam, the writer met another former student of algae from Banaras, Mrs. Baruah. She is now a teacher of botany in Cotton College. Her husband is Head of the Graduate Department of Botany in Gauhati University. They have both been instrumemntal in helping to form the Biological Society of Assam which held its first meetings in 1949.

Due particularly to Dr. M. O. P. Iyengar, Madras has been an important center of phycological research for some time. He has now retired as Head of the Botanical Laboratory of Madras University and continues his very active interest in algae. Papers of a num-

ber of his students have been published, including those of Dr. R. Subrahmanyan who is specializing on the diatoms. He is now plankton specialist for the Central Government Marine Fisheries Research Institute with headquarters at Madras. At the same institute is another algologist, Dr. Frances Thivy, who received training at the University of Michigan under Dr. W. R. Taylor.

Mr. T. V. Desikachari, Mr. K. G. Viraraghavan and Mr. S. Doraiswami are three more phycologists who received their training at Madras under Dr. Iyengar. The first is now teaching at Madras University and is specializing on fresh-water plankton. The second is algologist for the King Institute for Biological Research at Guindy near Madras, while the third is teaching at Alagappa Chettiar College, Karaikudi, Madras Province.

Turning again to north and central India, one finds a number of algologists located in several of the larger cities. Dr. B. P. Pal who published on the Charophytes of Burma, is now Head of the Division of Botany at the Institute of Agricultural Research in Delhi. Dr. K. K. Nanda is the algologist at the University of Delhi. At Allahabad, Dr. A. K. Mitra has returned recently from England where he studied phycology under Dr. Fritsch, and is teaching in Allahabad University. At Lucknow, two botanists with the same last name are interested in algae. Mr. A. R. Rao is teaching in the Botany Department of Lucknow University and Dr. S. R. Naryan Rao has been associated with the late Dr. Birbul Sahni at the Institute of Paleobotany. At Nagpur in central India, Dr. R. L. Nirula has been a teacher of botany at the Science College of the University of Nagpur and has continued his interest in the algae with occasional collecting trips to the shores of the Arabian Sea.

Two additional well known phycologists are now in other fields of work. Dr. Pyare Lal Anand, who published on the marine algae of Karachi, has moved from Lahore in the Punjab and is Food Administrator at Bombay. Mr. A. K. Randhawa, also formerly of Lahore, and who published a number of papers on the green algae, is now Deputy Commissioner at Ambala, East Punjab.

In Pakistan, Mr. Sher Ahmed Lodhi, who is a member of the Phycological Society of the Americas is teaching at the Government College of the University of Punjab at Lahore. At his invitation, the writer gave a talk on algae before the students of botany at the university.

In the recent past, India has had at least four important centers for the study of algae, Calcutta, Banaras, Madras and Lahore. Several of the leaders at these centers received their early training in England under Dr. Fritsch. Most of their research on algae has been in the fields of taxonomy and morphology. With workers retiring and moving away from the four centers, and with the new governments of India and Pakistan emphasizing practical research, the younger algologists are taking up their work with fisheries and agricultural institutes or else leaving the field of phycology entirely. Most of the new research on algae, therefore, is likely to be in ecology and limnology. The excellent training and the enthusiasm of these younger workers are making it possible for their contributions to be of high calibre.

It has been a pleasure and an inspiration to be able to meet and to talk with so many of the phycologists of India and Pakistan. With but three exceptions, the writer was able to see personally all of the algologists referred to in this article.

Top row (left to right) : Dr. M. O. P. Iyengar, Dr. K. Biswas.
Bottom row : Dr. B. P. Pal, Dr. R. N. Singh, Dr. Y. Bharadwaja, Mr. J. R. Misra.

AN ECOLOGICAL STUDY OF THE RELATION-SHIP BETWEEN DIRECTION OF SLOPE, ELE-VATION AND FOREST COVER IN BROWN COUNTY, INDIANA

By Carl R. McQueeney

The complexities of our deciduous forests, though constantly under the scrutiny of investigators from various fields of botany, present many problems which are poorly understood. Each area, regardless of size, presents new problems which may or may not be peculiar to the area in question. For this reason, it is imperative that as problems arise, they be treated in a quantitative, comparative manner. The primary object of this study is to illustrate the limits placed upon various species of tall trees by environmental factors introduced as a result of the direction and angle of the exposure, as well as the elevation, with special reference to sugar maple.

The area considered herein lies near the northernmost tip of unglaciated Indiana in the eastern part of Brown County. The phytosociological balance is in a sensitive state, due at least in part to the relationship of climate to physiography. Extensive ecological studies of this general region have been made by Friesner and Potzger, resulting in a more thorough understanding of the vegetative complex (11, 15, 18).

METHODS

The land on which this survey was made is owned by Mr. Joseph DeWess and lies on the north side of state road 46, eight miles east of Nashville. The terrain is cut by deep twisting valleys in such a way that slopes facing all directions are available. Care was taken to select slopes which faced directly east, north, south and west, respectively. Each slope was divided into two areas consisting of lower and upper elevations, the line of demarcation between upper and lower areas is the approximate upper limit in this area for Acer saccharum,* using the east-facing slope as a standard. The vertical elevation of

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* The species *Acer nigrum* was included in all tabulations with *Acer saccharum* due to the similarity of the two species.

this line is 48 feet above the valley floor. The line of demarcation for the west slope is 70 feet above the valley floor. The angle of each slope was recorded.

Sampling was by means of 100 sq. meter quadrats which were spaced 10 meters apart except where crowded conditions made this impossible. Tabulations were made on the basis of 25 quadrats for each area, except areas D and G where the slopes changed direction, curtailing the available space to 20 quadrats each. All woody species one meter or more in height were tabulated to illustrate reproduction and those one inch or more D.B.H. were measured and tabulated. All tabulations were made during the winter of 1948-49 while crown cover was absent.

OBSERVATIONS

A total of 47 woody species was found in the combined areas studied, 22 tall trees, 9 small trees and tall shrubs, and 16 small shrubs including one liana. The species were not evenly distributed on the four slopes, several of the total species being absent from each (table IV). The upper elevation of the south-facing slope, Area F, supported a total of 16 species, while on the north, east and west exposures, the total species present ranged from 26 to 28 for upper elevations and from 28 to 30 for lower elevations.

The most representative member of the dominant tall tree species was *Quercus alba* which was present in significant numbers in all areas, reaching its maximum development in the upper elevation of the south-facing slope where, with *Q. velutina,* it controlled the crown cover (table III). *Carya glabra* and *Acer rubrum* were also quite well represented in all areas in comparison to other tall tree species. The secondary layer was dominated overall by three major species, *Cornus florida, Ostrya virginiana* and *Sassafras albidum* with exceptions as later described. *Hamamelis virginiana, Smilax rotundifolia* and *Viburnum acerifolium* were the most widely distributed and abundant shrubs.

On the east-facing slope, lower elevation, the following trees were dominant: *Acer saccharum, Fagus grandifolia, Quercus alba,* and *Q. velutina.* Quercus played a more important part in controlling the crown cover, though the trend of succession appears to favor the Acer-Fagus type of dominance. The secondary layer was controlled by *Ostrya virginiana* and *Sassafras albidum,* and the shrub layer by

Hamamelis virginiana, Smilax rotudnifolia and *Viburnum aceri-folium*. In contrast, the upper elevation of the same slope was clearly dominated by *Quercus alba, Q. velutina* and to a lesser extent *Carya glabra* in the tall tree class and *Cornus florida, Ostrya virginiana* and *Sassafras albidum* in the secondary layer. The shrub layer was controlled by the same species with *Smilax rotundifolia* forming a dense tangle in several of the upper quadrats (table I).

The north-facing slope presents quite a different picture, with *Acer saccharum* and *Fagus grandifolia* clearly dominating the lower elevation while they share the upper elevation with *Quercus alba* and *Q. borealis maxima*. The upper elevation of the north-facing slope thus parallels the lower elevation of the east-facing slope, though in the former, Acer-Fagus controls more of the crown cover than Quercus. The secondary layer was controlled by *Carpinus caroliniana, Cornus florida,* and *Ostrya virginiana* in both elevations with the addition of *Sassafras albidum* on the upper elevation. *Lindera benzoin, Smilax rotundifolia* and *Viburnum acerifolium* controlled the shrub layer of the lower elevation and *Corylus americana, Hamamelis virginiana, Smilax rotundifolia,* and *Viburnum acerifolium* controlled the upper elevation (table I).

Seven species were important in controlling the crown cover of the lower elevation of the south-facing slope, the most prominent of which was *Fagus grandifolia*. *Acer saccharum, A. rubrum, Carya ovata* and *Quercus velutina* shared the crown cover with Fagus. The difference between upper and lower elevations was more marked on this slope, the crown cover of the upper elevation being controlled almost exclusively by *Quercus alba* and *Q. velutina*. The secondary layer was controlled by *Cornus florida, Ostrya virginiana* and *Sassafras albidum* on the lower elevation and by *Cornus florida* and *Sassafras albidum* on the upper elevation. The important shrubs of the lower elevation were *Corylus americana, Hamamelis virginiana, Lindera benzoin,* and *Smilax rotundifolia* while *S. rotundifolia* and *Viburnum acerifolium* controlled this layer on the upper elevation (table I).

The dominating species on the west-facing slope consisted of *Fagus grandifolia* and three species of Quercus. Fagus, *Q. alba* and *Q. borealis maxima* dominated the lower elevation, and Fagus, *Q. alba* and *Q. velutina,* the upper elevation. *Acer saccharum, A. rubrum* and *Carya glabra* were present but of minor importance. The secondary layer was controlled by *Carpinus caroliniana, Cornus florida* and

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Ostrya virginiana in the lower elevation, and by *O. virginiana, C. florida* and *Sassafras albidum* on the upper elevation. *Viburnum acerifolium* and *Smilax rotundifolia* dominated the shrub layer in both elevations. *Rubus allegheniensis* was also present in significant numbers in several quadrats of the upper elevation (table I).

On all exposures, a correlation between elevation and the presence of *Acer saccharum* and *Fagus grandifolia* was evident. This was especially true of the south-facing slope where the habitat was more xerophytic on the upper elevation. On this slope *Acer saccharum* and *Fagus grandifolia* were both prominent on the lower elevation, while *F. grandifolia* was completely absent, and *A. saccharum* was represented by only two stems on the upper elevation. A similar condition was observed on the east-facing slope. On the north and west-facing slopes, though this condition was present, the correlation was considerably reduced (fig. 2).

The combined species of Quercus showed a correlation on north, south and east-facing slopes, which was the reverse of the correlation between elevation and Acer-Fagus. This was especially pronounced on the south-facing slope where Quercus maintained exclusive control of the upper elevation (table III). The combined species of Carya did not show this correlation but appeared to reach its maximum development in the transitional area between the most mesophytic and more xerophytic types of habitat, hence being more prominent on the lower elevations of east and south-facing slopes and the upper elevations of north and west-facing slopes (table III). This apparent tendency toward the preference of a habitat more mesophytic than that best suited to the more xerophytic species of Quercus may be due partially to selective cutting. *Vaccinium stamineum* var. *neglectum,* a comparatively rare species found only in the unglaciated area (8), was found on the west-facing slope. Deam (8) lists this species as being near its western limits. Another species of more or less infrequent occurrence, *Carya tomentosa,* was found on the upper elevation of the west-facing slope. Deam (8) has listed no record of this species from Brown County.

DISCUSSION

The student of modern plant ecology must base many of his concepts upon the literature of those who have preceded him, and upon the greatly disturbed remains of a vegetation which is no longer con-

Fig. 1

Fig. 2

Acer saccharum

Fagus

Fig. 3

Quercus

Carya

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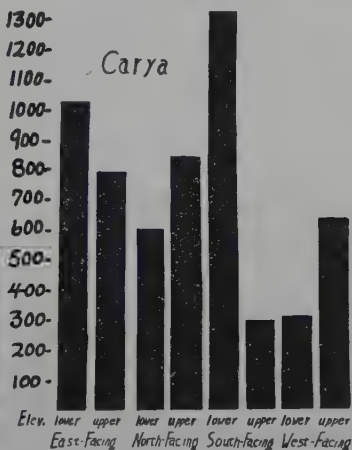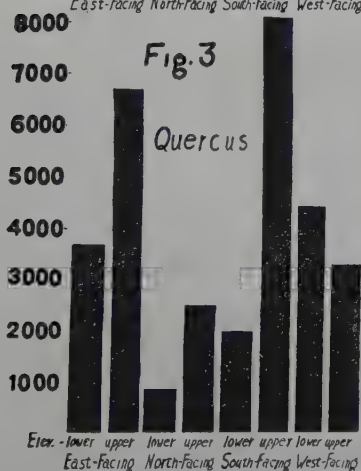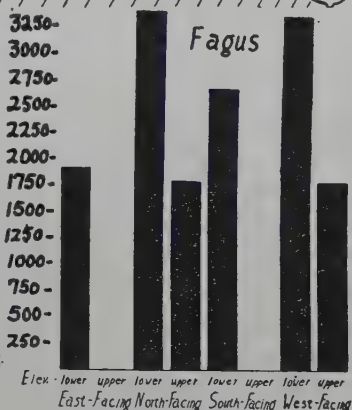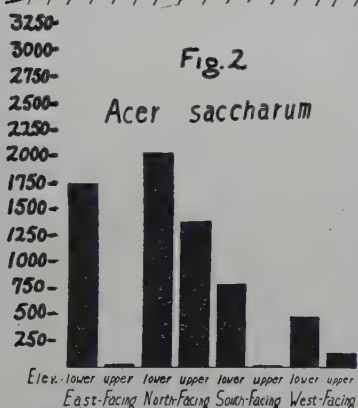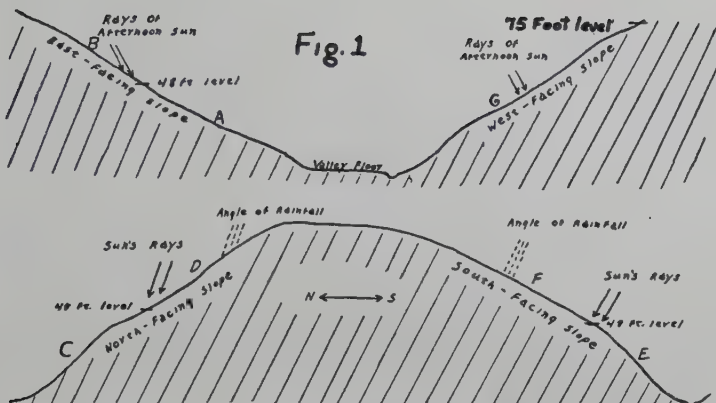
trolled by natural phenomenona alone. The complexities wrought by nature are increased ten-fold by the destructive hand of man. A forested area such as was studied for this paper can never give positive proof as to what associations might exist if there had been no disturbance. The conditions that one finds in disturbed areas are perhaps even more important than those found in forest primeval in that they show the trend of succession.

Indiana, as described by Friesner (9), is a "critical botanical area" in which many species are near their northern or western limits. Hence, it follows that slight climatic, edaphic, or physiographic variations may be responsible for definite vegetative differences. This is especially true where slopes are concerned since the presence of hills makes variations of these factors a certainty.

Visher (22) in describing the dynamics of the slope concludes that in Indiana four major climatic differences are significant on north and south-facing slopes: (1) North-facing slopes remain snow-covered longer and are thus protected from excessive run-off and alternate freezing and thawing. (2) Alternate freezing and thawing on south-facing slopes results in heaving of top soil and killing of shallow roots, which in turn increases erosion. (3) "The rains of Indiana come largely with southerly or southeasterly winds and beat down slightly stronger and more abundantly on south-facing than on north-facing slopes." (4) Warm season temperatures are greater on south-facing slopes, increasing evaporation (fig. 1).

There is some controversy as to whether southeasterly or southwesterly surface winds accompany most rains. According to a report by the United States Weather Bureau (20) southern Indiana "comes under the influence of both northwest and southwest storms, and it lies in the path of a considerable number of the latter which pass up the Ohio Valley." Monthly climatological reports for Indianapolis (21) show that rains were accompanied by both southeasterly and southwesterly winds to a similar degree during a period of two years.

The angle of inclination may also be of great importance in determining the vegetative complex due to an increase in run-off. Braun-Blanquet (1) states that the indirect effect of the angle of inclination on vegetation is due to the influence on the water supply and the shifting of the angle of incidence of the sun's rays. The nature of the underlying strata may also greatly affect water relation-

ships (23). According to Logan (14) Brown County is within the outcrop of Borden rocks.

The function of slopes in Indiana is thus to affect the vegetation to a degree which is a direct result of the balance set up between topography, edaphic factors and climate. This balance is affected by the direction and angle of exposure, elevation, protection afforded by terrain, soil type, intensity of rainfall, temperatures and evaporation, plus other somewhat less obvious factors.

Friesner and Potzger (11) have shown that in this part of Indiana, evaporation was higher and available soil moisture lower on south-facing than on north-facing slopes during late spring and summer seasons. In a study of microclimate in central Indiana, Potzger (16) found that "surface soil had 30% and soil at six-inch depths 28%, more moisture on the north than on the south slope."

Potzger (15), in his studies of "Topography and Forest Types in Indiana," states, "the transition from beech-maple on the north-facing slopes to oak-hickory on the south-facing slopes is not gradual but abrupt and decisive." In the present study this was found to be true not only for the north and south-facing slopes but also for the upper and lower elevation of the south-facing slope. Area E, the lower elevation of the south-facing slope, was protected to a large degree by a north-facing slope on the opposite side of a deep ravine. At the point where the influence of the north-facing slope was no longer apparent on the south-facing slope, the angle of inclination rapidly changed from about 25° to 18° and the vegetation changed from the "mixed mesophytic" community to an oak community in the space of a few yards. The term "mixed mesophytic" was taken from Braun (2). Such changes in vegetation are to be expected for as Gleason (12) states, "abrupt transitions are in every case correlated with abrupt differences in the immigrating plant population." A comparatively slight difference in vegetation was noted on the two respective elevations for the north-facing slope where better protection from climatic conditions was present.

The east- and west-facing slopes were located on opposite sides of a wide valley and hence were in no way protected. It is apparent that the afternoon sun would in this case cause the west-facing slope to be more xerophytic than the east-facing slope. Visher (22) points out that in the United States, west-facing slopes become warmer than

east-facing slopes. This difference in temperature may be partially responsible for the fact that *Acer saccharum* was less prominent on the west-facing slope. Costello (7) observed that corresponding associations were found higher on east-facing than west-facing slopes along the Missouri River.

The marked zoning of species in relation to elevation as especially illustrated in the case of *A. saccharum* (fig. 2) is probably due primarily to soil moisture conditions. *Fagus grandifolia* reacts to zoning in a similar manner (fig. 2) and in many cases shows a greater sensitivity to water relationships. There is considerable evidence that other factors may be of importance, however, as may be seen on the west-facing slope of this area. On this slope, Fagus was prominent in both lower and upper elevations, while *A. saccharum* was greatly restricted. This might lead one to say that Fagus has a wider range of habitat, concerning moisture conditions, than *A. saccharum* if it were not for the fact that, as Potzger (17) states, "*A. saccharum* may invade and ecese in habitats which are too dry for Fagus." When opposing conditions such as this are evident, it is obvious that factors other than moisture conditions are active in determining the vegetative complex.

Friesner and Ek (10) in comparing microclimatic factors with species distribution in an area of poor surface drainage, found that Acer-Quercus-Fagus communities occurred on less compact, better aerated soils than Quercus-Ulmus communities. This led Secor (19) to attribute the failure of *A. saccharum* to successfully invade certain areas of the Illinoian Drift Plain to drainage, soil aeration and surface moisture factors. In areas where surface drainage is obviously rapid and the direction of exposure determines to a large degree the amount of evaporation, it is reasonable to expect that the soil on a south-facing slope would be more compact and more poorly aerated than that of a corresponding north-facing slope, due to a lack of humus in the former. Thus poorer aeration of the soil in the areas under consideration may be a factor which tends to prevent the invasion of *Acer saccharum* on the dryer portions of south-facing slopes. This factor probably is important in this area only when other factors are sufficiently near the optimum to remove them from the role of limiting factors. Another factor in favor of the soil structure theory lies in the comparatively small number of sugar maple on the lower eleva-

tion of the south-facing slope where the steepest places were covered with less litter and fewer stems of sugar maple.

Acid soils may also be an important factor in the limiting of *A. saccharum* in certain areas, though the general trend of thought does not favor this theory (10, 11, 19). No tests were made to determine soil acidity; the abundance of *Gaylussacia baccata* and *Vaccinium vacillans,* however, is an indication that the soil of the upper elevations of the west-facing and south-facing slopes is acid. It has been well established that these two species are indicators of acid soil (5, 24). The hydrogen ion concentration may be due to what Gleason (12) describes as the "environmental control of the physical factors by the plant life itself."

In a study of a nearby area (18), it has been shown that the exposure influences the number of species present. The authors found that east and west-facing slopes appeared to support less species than north and south-facing slopes. They attributed this partially to a reduced number of quadrats from the former exposures. In the DeWess area, however, the number of quadrats from each slope was more nearly the same and opposite results were obtained. The total species on each slope was as follows: east-facing, 35 species; west-facing, 35 species; south-facing, 31 species; north-facing, 30 species. This indicated that east and west-facing slopes may support a greater variety of species, possibly due to greater competition on the north-facing slope and more rigorous habitat on the south-facing slope. It may, on the other hand, be due to disturbance. Cobbe (6) found a larger number of species on northern slopes in southwestern Ohio.

Previous papers have shown that elevation has an indirect effect upon the vegetation. Cain, Friesner and Potzger (4) described the variations of vegetation as influenced by altitude on a river bluff. They found that beech and maple were more frequent on the lower levels while oak and hickory were more frequent on the upper levels. A similar but somewhat accentuated condition was described by Little (13) in Caddo County, Oklahoma, where relic colonies of *A. saccharum* associated with other mesophytic species dominated the canyon floor, and the more xerophytic canyon rims, 30 to 70 feet above, supported several species of Quercus and Juniperus virginiana. Braun (3) observed that in the Cumberland Mountains, beech extended about half the distance up the south and west-facing slopes and two-thirds or more of the distance up the north and east-facing slopes.

Each individual area of this study proved to be an isolated vegetative community surrounded by other communities of similar species but of different composition. The forces of succession constantly struggle toward a homogeneous forest association while the overpowering microclimatic conditions repel each attempted invasion. Beyond a doubt, an unlimited number of sugar maple seeds germinate above the 48-foot level of the south and east-facing slopes each year, only to perish each summer. Hence, as Potzger (16) has pointed out, the microclimate in central Indiana will remain stable as long as there is no change in the macroclimate.

SUMMARY AND CONCLUSIONS

1. This study deals with the vegetative complex of north, south, east, and west-facing slopes of an area in Brown County, Indiana.

2. Each slope was divided into upper and lower elevations to show the indirect effect of elevation and studied by means of 100 sq. meter quadrats.

3. Forty-seven woody species were encountered, 22 tall trees, 9 small trees and tall shrubs, and 16 small shrubs including 1 liana.

4. The dominant tall trees species were: *Quercus alba, Fagus grandifolia, Acer saccharum, Q. velutina, Q. borealis maxima, Carya glabra,* and *A. rubrum.* These species were represented in different proportions for most areas.

5. The north-facing slope supported the most mesophytic and the south-facing slope the most xerophytic species.

6. The upper elevations tended to support the more xerophytic species and the lower elevations the more mesophytic species.

7. *Acer saccharum* was prominent on the lower elevations of the east and south-facing slopes but dropped out abruptly at the 48-ft. level. A similar correlation was observed for *Fagus grandifolia.*

ACKNOWLEDGMENTS

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TABLE I

Stems present in lower and upper elevations of each of the four slopes. East-facing: lower elevation (A), upper (B); north-facing: lower elevation (C), upper (D); south-facing: lower elevation (E), upper (F); west-facing: lower elevation (G), upper (H). All areas 25 quadrats each except (D) and (G).

Species	Area	Below 1"	1-2	3-5	6-10	11-15	16-20	Above 20"	Total above 1"	F. I.	Basal Area sq. in.
Tall Trees											
	A	15	6	10	6				22	44	319.7
	B	32	14	17	2				33	72	268.6
	C	9	5	6	6		1		18	52	575.7
	D	14	11	16	4				31	70	412.6
Acer rubrum	E	4	4	2	4	4			14	44	681.7
	F	44	57	11					68	96	179.1
	G	28	3	7	3				13	45	223.8
	H	105	13	12	7				32	80	439.0
	A	98	173	63	7	1		1	245	100	1740.7
	B	16	5	2					7	24	22.8
	C	70	125	44	6	4		1	181	100	2016.9
	D	29	46	28	6		1	1	81	90	1091.1
A. saccharum	E	92	53	16	5	3			77	72	776.0
	F		1	1					2	04	7.9
	G	55	11	11	1		1		24	85	422.5
	H	5	1	1		1			3	16	136.7

TABLE I—(Continued)

Stems present in lower and upper elevations of each of the four slopes. East-facing: lower elevation (A), upper (B); north-facing: lower elevation (C), upper (D); south-facing: lower elevation (E), upper (F); west-facing: lower elevation (G), upper (H). All areas 25 quadrats each except (D) and (G).

Species	Area	Below 1"	1-2	3-5	6-10	11-15	16-20	Above 20"	Total above 1"	F. I.	Basal Area sq. in.
Carya	A	1		4	1				5	08	116.8
	B				1				1	04	63.6
cordiformis	C	2								08	
	E	1			1				1	08	50.3
	G	1								05	
	H	2								08	
	A	13	14	20	4				38	68	440.6
	B	52	52	24	3	1			80	92	573.4
C.	C	5	21	9	8				38	68	489.3
	D	13	13	14	5				32	70	480.7
glabra	E	3	2	6	3	2			13	48	452.4
	F	26	70	13					83	92	221.5
	G	13	11	7	2				20	65	201.4
	H	87	19	24	6				49	84	511.9

TABLE I—(Continued)

Stems present in lower and upper elevations of each of the four slopes. East-facing: lower elevation (A), upper (B); north-facing: lower elevation (C), upper (D); south-facing: lower elevation (E), upper (F); west-facing: lower elevation (G), upper (H). All areas 25 quadrats each except (D) and (G).

Species	Area	Below 1"	1-2	3-5	6-10	11-15	16-20	Above 20"	Total above 1"	F. I.	Basal Area sq. in.
	A	12	9	20	4				33	72	461.0
	B	2	7	8	2				17	20	153.9
	C				3				3	12	117.0
	D	1	3	10	3				16	50	212.8
C. ovata	E	17	23	28	6	2			59	76	830.0
	F	2	2	4	1				7	24	91.9
	G	21	3		1				4	50	40.8
	H		2	3	2				7	24	122.5
C. tomentosa	H	5		3					3	04	33.8
Celtis occidentalis	G	1								05	
	A	5	3	5	4	5		1	18	32	1882.6
	B	1								04	
Fagus grandifolia	C	12	57	16	7	7	2	3	92	96	3420.4
	D	11	7	3	3	1	2	1	17	60	1395.7

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TABLE I—(Continued)

Stems present in lower and upper elevations of each of the four slopes. East-facing: lower elevation (A), upper (B); north-facing: lower elevation (C), upper (D); south-facing: lower elevation (E), upper (F); west-facing: lower elevation (G), upper (H). All areas 25 quadrats each except (D) and (G).

Species	Area	Below 1"	1-2	3-5	6-10	11-15	16-20	Above 20"	Total above 1"	F. I.	Basal Area sq. in.
Fagus grandifolia	E	10	39	20	31	4	1		95	80	2624.0
	G	11	5	9	21	9		1	45	80	2646.3
	H	24	15	20	16	4		1	56	76	1760.8
	A	3	2	9	6	1			18	40	445.3
	B	5		1					1	16	7.1
	C	10	8	6	2				16	52	181.4
	D	3	2	1					3	20	18.8
Fraxinus americana	E	35	9	6	2				17	64	201.4
	F	7								24	
	G	7		2					2	30	18.1
	H	1								04	
F. biltmoreana	B	1								04	
	B				1				1	04	63.6
Juglans cinerea	C			1	2				3	08	121.0
	D				2				2	10	127.2

TABLE I—(Continued)

Stems present in lower and upper elevations of each of the four slopes. East-facing: lower elevation (A), upper (B); north-facing: lower elevation (C), upper (D); south-facing: lower elevation (E), upper (F); west-facing: lower elevation (G), upper (H). All areas 25 quadrats each except (D) and (G).

Species	Area	Below 1"	1-2	3-5	6-10	11-15	16-20	Above 20"	Total above 1"	F. I.	Basal Area sq. in.
J. nigra	H	1	2						2	04	1.6
Juniperus virginiana var. crebra	B	1								04	
Liriodendron tulipifera	A			1		1			2	08	120.2
	C	1		2		1			3	08	127.2
	D	1	1		1	1			3	15	152.4
	E				1	2			3	08	388.0
	G	4	1						1	15	3.1
Nyssa sylvatica	A		3	6	3				12	28	225.7
	B	3	3						3	16	9.4
	C	1	6	1					7	20	26.7
	D	2	2	1	1				4	25	61.3
	E	5	3						3	12	2.4
	F	4	6						6	24	7.1
	G	9	3	1					4	20	14.1
	H	20	2	1					3	24	11.0

TABLE I—(Continued)

Stems present in lower and upper elevations of each of the four slopes. East-facing: lower elevation (A), upper (B); north-facing: lower elevation (C), upper (D); south-facing: lower elevation (E), upper (F); west-facing: lower elevation (G), upper (H). All areas 25 quadrats each except (D) and (G).

Species	Area	Below 1"	1-2	3-5	6-10	11-15	16-20	Above 20"	Total above 1"	F.I.	Basal Area sq. in.
Populus grandidentata	B		3	1	5				9	08	351.9
	D	1		1					1	05	12.6
	H	1		2	2				4	12	93.5
Prunus serotina	A	2		3	7	1			11	32	398.2
	B	7	1	2	1	1			5	20	161.0
	C	1	1	1	3				5	16	161.0
	D	2	1	1	3				5	30	142.9
	E	7	4	1	2				7	28	97.4
	G	5	2						2	10	1.6
	H	1								04	
Quercus alba	A	4	4	11	19	1			36	60	1898.1
	B	11	23	75	59	2		1	159	96	3767.6
	C	2	6	9	3	1			19	56	346.4
	D	8	4	10	13	1			28	70	744.9
	E	18	8	7	5	1			21	54	479.9
	F	18	88	139	90	2	1		320	100	5771.9
	G	8	4	13	20	7			44	55	2083.2
	H	33	12	27	17	5			61	76	1671.1

TABLE I—(Continued)

Stems present in lower and upper elevations of each of the four slopes. East-facing: lower elevation (A), upper (B); north-facing: lower elevation (C), upper (D); south-facing: lower elevation (E), upper (F); west-facing: lower elevation (G), upper (H). All areas 25 quadrats each except (D) and (G).

Species	Area	Below 1"	1-2	3-5	6-10	11-15	16-20	Above 20"	Total above 1"	F.I.	Basal Area sq. in.
Q. borealis var. maxima	C					1			1	04	132.7
	D		1		4	3		1	10	35	1076.8
	E	1	1	1		2	1		4	12	523.1
	G	33		2	6	2	1	1	12	50	1288.1
	H	1								04	
Q. velutina	A		3	2	13	9			27	56	1756.2
	B	1	3	5	20	10	2		40	76	2921.5
	C	2	6	1	3		1		11	32	420.2
	D	2				1	1		1	05	153.9
	E	2	2	5	3	4	1		15	24	923.6
	F	2		7	10	12	1	1	31	56	2642.7
	G	7	1		1				2	25	79.3
	H	31	4	6	12	7			29	64	1584.9
Ulmus americana	A	5								12	
	C					1			1	04	113.1
	E	2	2	3	1				6	24	96.6
	G	9								15	

TABLE I—(Continued)

Stems present in lower and upper elevations of each of the four slopes. East-facing: lower elevation (A), upper (B); north-facing: lower elevation (C), upper (D); south-facing: lower elevation (E), upper (F); west-facing: lower elevation (G), upper (H). All areas 25 quadrats each except (D) and (G).

Species	Area	Below 1"	1-2	3-5	6-10	11-15	16-20	Above 20"	Total above 1"	F. I.	Basal Area sq. in.
U. rubra	A	25	1	1	6				8	44	293.0
	B	12								25	
	G	14		1					1	15	19.6
Small Trees *Tall Shrubs*	A	1	2						2	08	1.6
	B	6	3						3	20	7.1
	C		3						3	08	7.1
	D	1								05	
Amelanchier canadensis	E		5						5	12	8.6
	G	13								10	
	H		1						1	04	0.8
Asimina triloba	E	1								04	
Carpinus caroliniana	A	13	3	2					5	28	23.6
	C	11	7	1					8	48	14.9
	D	13	7	2					9	35	26.7

TABLE I—(Continued)

Stems present in lower and upper elevations of each of the four slopes. East-facing: lower elevation (A), upper (B); north-facing: lower elevation (C), upper (D); south-facing: lower elevation (E), upper (F); west-facing: lower elevation (G), upper (H). All areas 25 quadrats each except (D) and (G).

Species	Area	Below 1"	1-2	3-5	6-10	11-15	16-20	Above 20"	Total above 1"	F. I.	Basal Area sq. in.
Carpinus caroliniana	E	7	1						1	24	0.7
	G	111	8						8	44	18.1
	H	33	2						2	36	1.6
Cercis canadensis	A			2					2	04	14.1
	E	3	2						2	04	6.3
	A	6	1	1					2	24	7.9
	B	71	19	4					23	84	63.1
	C	36	6	3					9	68	58.1
	D	31	14	7	2				23	90	173.6
Cornus florida	E	40	18	3	1				22	60	88.3
	F	15	12						12	36	21.2
	G	60	11						11	70	18.1
	H	43	3	5					8	68	53.7
Crataegus sp.?	E	1								04	

TABLE I—(Continued)

Stems present in lower and upper elevations of each of the four slopes. East-facing: lower elevation (A), upper (B); north-facing: lower elevation (C), upper (D); south-facing: lower elevation (E), upper (F); west-facing: lower elevation (G), upper (H). All areas 25 quadrats each except (D) and (G).

Species	Area	Below 1"	1-2	3-5	6-10	11-15	16-20	Above 20"	Total above 1"	F. I.	Basal Area sq. in.
Morus rubra	A	1								04	
Ostrya virginiana	A	215	25	9					34	96	129.6
	B	111	19	2					21	60	59.7
	C	114	5	4	1				10	68	115.5
	D	146	25	9					34	85	149.5
	E	92	6	4					10	72	56.5
	F		1						1	04	3.1
	G	168	20	7					27	90	104.5
	H	158	41	2					43	80	74.6
Sassafras albidum	A	5	3	11					14	36	166.5
	B	23	9	18	1				28	56	238.0
	C	10		1	1				2	24	98.2
	D	5	2	9	2				13	64	191.6
	E	6		7					7	12	98.2
	F	16	5	5					10	44	46.3
	G	43								35	
	H	55	1	4	5				10	44	322.8

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TABLE I—(Continued)

Stems present in lower and upper elevations of each of the four slopes. East-facing: lower elevation (A), upper (B); north-facing: lower elevation (C), upper (D); south-facing: lower elevation (E), upper (F); west-facing: lower elevation (G), upper (H). All areas 25 quadrats each except (D) and (G).

Species	Area	Below 1"	1-2	3-5	6-10	11-15	16-20	Above 20"	Total above 1"	F. I.	Basal Area sq. in.
Shrubs											
	D	47								70	
Corylus americana	E	24								32	
	G	3								10	
	A	6								04	
Dirca palustris	C	5								08	
	D	1								05	
	E	1								04	
Gaylussacia baccata	H	*									
Hamamelis virginiana	A	15								44	
	B	21								28	
	C	5								20	
	D	16								40	

* Stems of these species were present as indicated but were not tabulated.

TABLE I—(Continued)

Stems present in lower and upper elevations of each of the four slopes. East-facing: lower elevation (A), upper (B); north-facing: lower elevation (C), upper (D); south-facing: lower elevation (E), upper (F); west-facing: lower elevation (G), upper (H). All areas 25 quadrats each except (D) and (G).

Species	Area	Below 1"	1-2	3-5	6-10	11-15	16-20	Above 20"	Total above 1"	F. I.	Basal Area sq. in.
Hamamelis virginiana	E	17								36	
	F	8								08	
	G	16								40	
	H	11								24	
Hydrangia arborescens	A	1								04	
	B	1							/	04	
Lindera benzoin	A	2								04	
	C	15								16	
	E	59								40	
Rubus allegheniensis	E	1								04	
	G	52								15	
R. occidentalis	B	1								04	
	G	1								05	
	H	10								04	

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TABLE I—(Continued)

Stems present in lower and upper elevations of each of the four slopes. East-facing: lower elevation (A), upper (B); north-facing: lower elevation (C), upper (D); south-facing: lower elevation (E), upper (F); west-facing: lower elevation (G), upper (H). All areas 25 quadrats each except (D) and (G).

Species	Area	Below 1"	1-2	3-5	6-10	11-15	16-20	Above 20"	Total above 1"	F.I.	Basal Area sq. in.
Sambucus canadensis	C	6								04	
Smilax glauca	A	1								04	
	B	2								08	
	F	11								16	
S. hispida	A	2								08	
	C	5								12	
	D	5								10	
	H	1								04	
S. rotundifolia	A	18								40	
	B	1464								72	
	C	26								28	
	D	30								20	
	E	193								96	
	F	443								88	
	G	36								20	
	H	286								64	

TABLE I—(Continued)

Stems present in lower and upper elevations of each of the four slopes. East-facing: lower elevation (A), upper (B); north-facing: lower elevation (C), upper (D); south-facing: lower elevation (E), upper (F); west-facing: lower elevation (G), upper (H). All areas 25 quadrats each except (D) and (G).

Species	Area	Below 1"	1-2	3-5	6-10	11-15	16-20	Above 20"	Total above 1"	F. I.	Basal Area sq. in.
Vaccinum stamineum var. neglectum	H	*									
V. vacillans	F	*									
	G	*									
	H	*									
	A	30								44	
	B	67								60	
	C	46								44	
Viburnum acerifolium	D	48								65	
	E	7								12	
	F	29								28	
	G	261								80	
	H	289								68	

* Stems of these species were present as indicated but were not tabulated.

TABLE I—(Continued)

Stems present in lower and upper elevations of each of the four slopes. East-facing: lower elevation (A), upper (B); north-facing: lower elevation (C), upper (D); south-facing: lower elevation (E), upper (F); west-facing: lower elevation (G), upper (H). All areas 25 quadrats each except (D) and (G).

Species	Area	Below 1"	1-2	3-5	6-10	11-15	16-20	Above 20"	Total above 1"	F. I.	Basal Area sq. in.
	A	5								16	
	B	16								44	
	C	4								12	
Vitis sp.?	D	4								20	
	E	5								16	
	F	5								20	
	G	1								05	

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TABLE II

Relation of Elevation to Presence of *Acer saccharum* and *Fagus grandifolia* on East-, North-, South-, and West-facing Slopes.

Slope Direction	Species	Area (Quads.)	Elevation above valley floor	Approx. angle of slope	Stems below 1"	Stems above 1"	F. I.	Basal Area sq. in.
East-facing	Acer	A (25)	Below 48 ft.	8.5°	98	245	100	1740.5
		B (25)	48-75 ft.	15.0°	16	7	24	22.8
	Fagus	A (25)	Below 48 ft.	8.5°	5	18	32	1882.6
		B (25)	48-75 ft.	15.0°	1	0	4	0
North-facing	Acer	C (25)	Below 48 ft.	28-34°	70	181	100	2016.9
		D (20)	Above 48 ft.	17.0°	29	81	90	1091.1
	Fagus	C (25)	Below 48 ft.	28-34°	12	92	96	3420.4
		D (20)	Above 48 ft.	17.0°	11	17	60	1395.7
South-facing	Acer	E (25)	Below 48 ft.	25-31°	92	77	72	776.0
		F (25)	Above 48 ft.	18.0°	0	2	4	7.9
	Fagus	E (25)	Below 48 ft.	25-31°	10	95	80	2224.0
		F (25)	Above 48 ft.	18.0°	0	0	0	0
West-facing	Acer	G (20)	Below 70 ft.	28.0°	55	24	85	442.6
		H (25)	75-145 ft.	28.0°	5	3	16	136.7
	Fagus	G (20)	Below 70 ft.	28.0°	11	45	80	2646.3
		H (25)	75-145 ft.	28.0°	24	56	76	1760.8

TABLE III

Relation of Elevation to Presence of Species of Carya and Quercus on East-, North-, South-, and West-facing Slopes

Slope Direction	Species of	Area (Quads.)	Elevation above valley floor	Approx. angle of slope	Total stems below 1"	Total stems above 1"	Combined basal areas—sq. in.
East-facing	Quercus (2 spp.)	A(25)	Below 48 ft.	8.5°	4	63	3654.2
		B(25)	48-75 ft.	15.0°	12	199	6689.0
	Carya (3 spp.)	A(25)	Below 48 ft.	8.5°	26	76	1018.4
		B(25)	48-75 ft.	15.0°	54	98	790.9
North-facing	Quercus (3 spp.)	C(25)	Below 48 ft.	28-34°	4	31	899.3
		D(20)	Above 48 ft.	17.0°	8	39	1975.6
	Carya (3) (2 spp.)	C(25)	Below 48 ft.	28-34°	7	41	606.3
		D(20)	Above 48 ft.	17°	14	48	693.5
South-facing	Quercus (3) (2 spp.)	E(25)	Below 48 ft.	25-31°	19	40	1926.6
		F(25)	Above 48 ft.	18°	20	351	8414.6
	Carya (3) (2 spp.)	E(25)	Below 48 ft.	25-31°	21	72	1332.7
		F(25)	Above 48 ft.	18°	28	90	313.4
West-facing	Quercus (3 spp.)	G(20)	Below 70 ft.	28°	48	58	3450.6
		H(25)	75-145 ft.	28°	65	90	3256.0
	Carya (4 spp.)	G(20)	Below 70 ft.	28°	35	24	242.2
		H(25)	75-145 ft.	28°	94	59	668.2

TABLE IV

Distribution and Density of Species on All Slopes

Tall trees, small trees & tall shrubs	Shrubs
1. Only stem below 1″ present	1. 1-10 stems present
2. 1-10 stems above 1″ present	2. 11-20 stems present
3. 11-20 stems above 1″ present	3. 21-50 stems present
4. 21-50 stems above 1″ present	4. 51-100 stems present
5. Over 50 stems above 1″ present	5. Over 100 stems present

*Stems present but not tabulated.

Exposure Species	East		North		South		West	
	A	B	C	D	E	F	G	H
Tall Trees								
Acer rubrum	4	4	3	4	3	5	3	4
A. saccharum	5	2	5	5	5	2	4	2
Carya cordiformis	2	2	1		2		1	1
C. glabra	4	5	4	4	3	5	3	4
C. ovata	4	3	2	3	5	2	2	2
C. tomentosa								2
Celtis occidentalis							1	
Fagus grandifolia	3	1	5	3	5		4	5
Fraxinus americana	3	2	3	2	3	1	2	1
F. biltmoreana		1						
Juglans cinera		2	2	2				
J. nigra								2
Juniperus virginiana, var. crebra		1						
Liriodendron tulipifera	2		2	2	2		2	
Nyssa sylvatica	3	2	2	2	2	2	2	2
Populus grandidentata		2		1				2
Prunus serotina	3	2	2	2	2		2	1
Quercus alba	4	5	3	4	4	5	4	5
Q. borealis maxima			2	2	2		3	1
Q. velutina	4	4	3	2	3	4	2	3
Ulmus americana	1		2		2		1	
U. rubra	2	1					2	
Total number species for each area	14	16	15	14	14	8	16	15
Small Trees and Tall Shrubs								
Amelanchier canadensis	2	2	2	1	2		1	2
Asimina triloba					1			
Carpinus caroliniana	2		2	2	2		2	2
Cercis canadensis	2				2			
Cornus florida	2	4	2	4	4	3	3	2

TABLE IV—(Continued)

Distribution and Density of Species on All Slopes

Exposure Species	East		North		South		West	
	A	B	C	D	E	F	G	H
Crataegus sp.					1			
Morus rubra	1							
Ostrya virginiana	4	4	2	4	2	2	4	4
Sassafras albidum	3	4	2	3	2	2	1	2
Total number species for each area	7	4	5	5	8	3	5	5

Small Shrubs

	A	B	C	D	E	F	G	H
Corylus americana				3	3		1	
Dirca palustris	1		1	1	1			
Gaylussacia baccata								*
Hamamelis virginiana	2	3	1	2	2	1	2	2
Hydrangia arborescens	1	1						
Lindera benzoin	1		2		4			
Rubus allegheniensis					1		4	
R. occidentalis		1					1	1
Sambucus canadensis			1					
Smilax glauca	1	1				2		
S. hispida	1		1	1				1
S. rotundifolia	2	5	3	3	5	5	3	5
Vaccinium stamineum neglectum								*
V. vacillans						*	*	*
Viburnum acerifolium	3	4	3	3	1	3	5	5
Vitis sp.?	1	2	1	1	1	1	1	
Total number species for each area	9	7	8	7	8	5	8	8
Total number all woody species	30	27	28	26	30	16	29	28

NITELLA SPANIOCLEMA GROVES & BULLOCK-WEBSTER VAR. NIDIFICA, NOV. VAR., FROM ALABAMA

By Fay Kenoyer Daily

An interesting Nitella was collected in Alabama, June 6, 1947, by Francis X. Lueth of the Department of Conservation, State of Alabama. In an initial study, some bits of material found loose in the packet were tentatively identified as *Nitella spanioclema* Groves & Bullock-Webster (2), a species apparently known only from Ireland. After obtaining some cotypic material, however, a complete study was made of the packet contents and a portion was seen to differ sharply in habit from the species. Whether the lax bits were broken from this "Tolypella-like" plant since it does show great variability or whether they represent other typical plants must remain for future collection to determine.

Primarily upon the basis of the difference in habit, a new variety is named.

Nitella spanioclema Groves & Bullock-Webster var. nidifica, nov. var. Plate I.

Cum habito *Tolypellae nidificae,* ramulis verticilli variis 3-10, segmentis ultimis ramulorum usualiter longioribus quam segmentis primariis; ceterum ut in typo.

With the habit of *Tolypella nidifica,* branchlets of the verticels variable 3-10, ultimate segments (ultimate rays) of the branchlets usually longer than the primary segments (primary or axial rays); otherwise as in the type.

A complementary diagnosis follows:

Habit: lower whorls lax of 3-4 branchlets, upper whorls crowded and producing several small adventitious branchlets and several branches at a verticel so that a "Tolypella-like" appearance is achieved; branches not only produced in the fundus of the verticel, but also arise in place of branchlets, often are aborted. Monoecious. Stem: ca. 0.75 mm in diameter. Sterile Branchlet: simple one-celled or

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PLATE I. *Nitella spanioclema* Groves & Bullock-Webster var. *nidifica*, nov. var.
1. Lax bit of plant, normal size. 2. "Tolypella-like" portion of plant, normal size.
3. Coronula of oogonium. 4. Bases of branchlets showing arrangement of adventitious branchlets at this node. 5. Oospore. 6. A small portion of the outer colored membrane of the oospore. 7. Simple sterile branchlet, greatly enlarged. 8. A portion from the "Tolypella-like" part of the plant, greatly enlarged. 9. A whorl from a lax bit of plant, greatly enlarged.

once furcate producing usually only one one-celled ultimate ray, the tip ranging from obtuse to acute. FERTILE BRANCHLET: 3-10 at a node, once or twice furcate, the ultimate ray usually longer than the axial ray, but often much reduced, bearing usually one one-celled ultimate ray (occasionally 2 but always one aborted), the tip ranging from obtuse to acute. OOGONIA AND ANTHERIDIA: together or at different nodes. OOGONIA: single or 2-3 together; coronula deciduous, upper cells ca. 0.025-0.036 mm high, lower cells ca. 0.018 mm high. OOSPORE: red brown, ca. 0.525 mm long, ca. 0.375 mm broad, 6 sharp ridges; outer colored membrane granulate and scabrous, obscurely reticulate, red brown. ANTHERIDIUM: (few seen) immature, ca. 0.33 mm in diameter, sometimes appearing to be stalked because of the reduction or abortion of rays produced at the node bearing an antheridium. Specimen seen: Alabama: Baldwin county; Mobile Delta south of Tensaw river bridge, Francis X. Lueth, June 6, 1947.

The American plant probably most nearly allied to the new variety is *Nitella californica* forma *nidifica* Allen (1) which differs primarily in having only once furcate branchlets and usually 2 ultimate rays at a node. Differences in compactness of form and the length of the ultimate rays are seen in contrasting *Nitella californica* Allen and the forma *nidifica* Allen. Differences of a similar nature serve to separate the new variety from *Nitella spanioclema* Groves & Bullock-Webster, but the contrast is more striking in this comparison.

The Herbarium
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Indianapolis, Indiana

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2. GROVES, J. AND G. R. BULLOCK-WEBSTER. The British Charophyta I. Nitelleae p. 108. London, 1920.

TOLYPELLA PROLIFERA LEONH. IN INDIANA

By Fay Kenoyer Daily

Although members of the genus Tolypella have been found in Illinois and Ohio, apparently none have been reported previously from Indiana. On September 10, 1947, at Pokagon State Park, Steuben county, Indiana, in one of the display ponds, *Tolypella prolifera* Leonh. was found by W. A. Daily and the author.

This specimen is very similar to the *Tolypella prolifera* Leonh. found in Nebraska by Dr. Walter Kiener and described by the author in 1946 (1) ; tending, however, toward production of fertile branchlets with ultimate rays having more cells and bearing more short mucronate end cells. A key to the genera of Characeae found in Nebraska was also given in the 1946 publication, and could be used for the Indiana Characeae, since the known members of this group found in Indiana are the same as are found in Nebraska.

The members of the Characeae are all similar in that they are made up of whorls of structures called branchlets occurring at succeeding nodes on the stem. Branchlets of a given whorl are usually more or less similar in size and structure. Differential characteristics are given in the following paragraphs.

The genus Tolypella (Plate I-A) contains plants having whorls of similar sterile branchlets as well as whorls of fertile branchlets. The sterile branchlets are usually simple unbranched structures of a few cells attached end to end ; however, they may be branched. The ultimate cells may be conical or elongate.

The fertile branchlets of members of the genus Tolypella have a main axis giving rise to lateral processes. The main axis is topped by an ultimate ray made up of one to several cells and usually long overtopping the rest of the branchlet. The lateral rays are smaller than the ultimate ray and are usually made up of several cells. A lateral ray may occasionally also give rise to lateral processes. The long overtopping ultimate rays and the crowding of the fertile whorls give the usual Tolypella a characteristic appearance by producing nest-like heads.

Antheridia and oogonia are produced laterally at the nodes of the

branchlet or at the base of the whorls of branchlets. The small crown of cells, the coronula, at the top of the oogonium is made up of 10 cells in 2 tiers of 5 cells each. The oospores are terete or cylindrical and slightly tapering at each end.

There is considerable variation in the appearance of the plant body in Nitella. Although heads may occasionally be produced, they differ from Tolypella in that they are usually symmetrical due to the furcation of the branchlet into more or less equal rays. Many Nitellas do not have crowded fertile whorls producing heads. In fact, some Nitellas do not have branchlets furcate to the extent shown in the illustration of *Nitella tenuissima* Kütz. (Plate I-B), but in the simplest form may have only one node giving rise to only one ultimate ray.

The antheridia in Nitella are terminally produced at the summit of a ray at a node. The oogonia are formed beneath the antheridia as a lateral outgrowth. The coronula is of two tiers of five cells each as in Tolypella. The oospores are flattened laterally.

In Chara (Plate I-C), the branchlet has a central axis as in Tolypella. Several nodes are usually found, each giving rise to one-celled processes called bracts.

The antheridia and oogonia are produced laterally at the branchlet nodes. The oogonium differs from that found in Nitella and Tolypella in having a five-celled coronula. The oospore is terete. At the base of the branchlets are one-celled structures called stipulodes.

Although some Charas do not have it, others develop cortication which means that the stem and branchlet internodes are covered by a layer of cells one cell in thickness. The illustration (Plate I-C, fig. 2) shows how the layer of cortication surrounds the central cell of the stem in cross section. Cortication is not found in Tolypella or Nitella.

The chief differential characteristics of the Characeae found in Indiana are compared for convenience in Table I.

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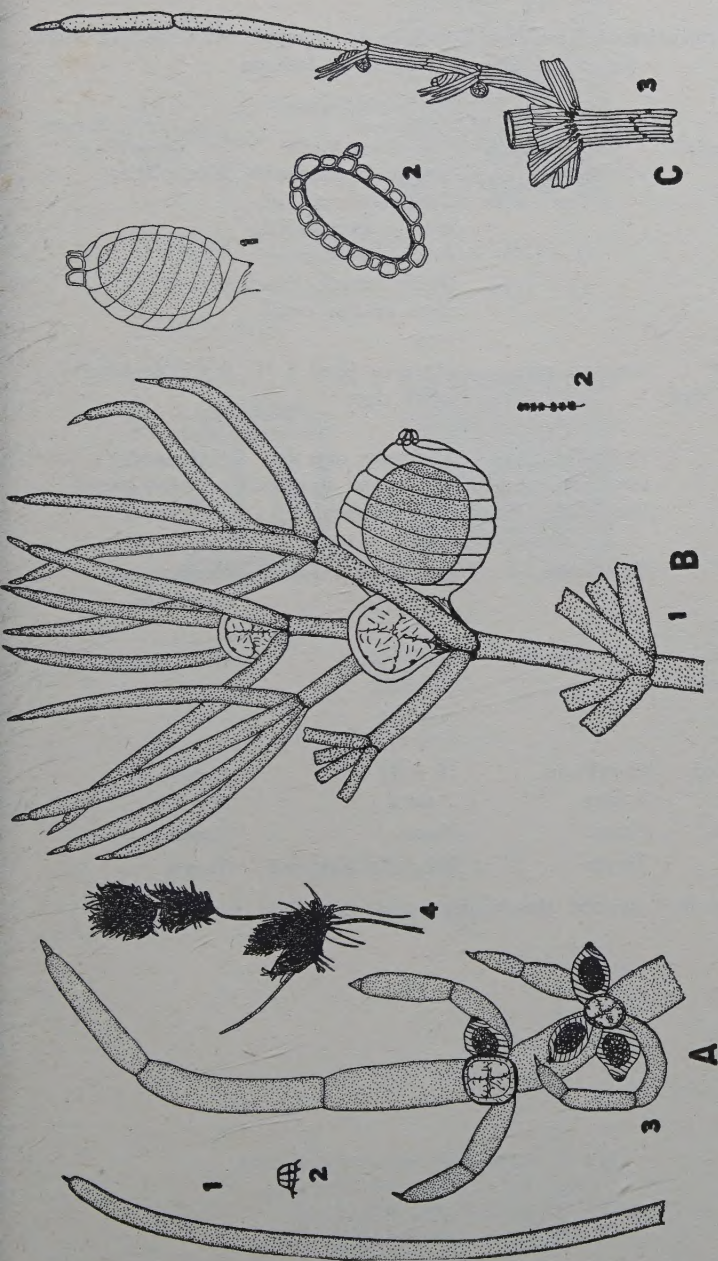
I-A. *Tolypella prolifera* Leonh. 1. Sterile branchlet. 2. Coronula of oogonium. 3. Fertile branchlet. 4. A portion of the plant, ½ natural size.

I-B. *Nitella tenuissima* Kütz. 1. A portion of a branchlet, showing only one of several similar rays in some cases, the other rays being represented by only basal portions. 2. Portion of plant, ½ natural size.

I-C. *Chara contraria* A. Br. 1. Oogonium. 2. Transverse section of the stem. 3. The basal portion of a whorl of branchlets arising from the stem, showing one branchlet completed.

TABLE I

Chief characteristics of the Genus Tolypella as compared with the two other Genera of Characeae found in Indiana

| | Family Characeae | | |
| | Sub-family Nitelleae | | Sub-family Chareae |
Characteristics	Genus Tolypella	Genus Nitella	Genus Chara
1. Fertile branchlet growth	Monopodial	Simple (1 node with 1 ultimate ray), obscurely monopodial, simply or successively furcate into more or less equal rays	Monopodial
2. Length of branchlet rays or bracts	Unequal rays	More or less equal rays	Variable bracts
3. Branchlet whorls	If fertile, clustered into nest-like heads	If fertile, may or may not be clustered into symmetrical heads	Not usually crowded except at apex
4. Branchlet and stem cortication	Ecorticate	Ecorticate	Corticate or ecorticate
5. Antheridia and oogonia	Both lateral	Antheridia-terminal, oogonia-lateral	Both lateral
6. Coronula of oogonium	10 cells in 2 tiers	10 cells in 2 tiers	5 cells in 1 tier
7. Stipulodes	None	None	Present
8. Oospore	Terete	Laterally flattened	Terete

This is a general classification and exceptions may occur.